TECHNOLOGY SURVEY

OF

MAJOR U . S. SHIPYARDS

1978

FOR THE DEPARTMENT OF COMMERCE

MARITIME ADMINISTRATION

BY

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ABSTRACT

This is a report on a technology survey of 13 major U. S. shipyards and 16 of the best comparable foreign shipyards. A standard procedure is followed in assigning one of four technology levels to a broad range of shipbuilding operations and processes in each shipyard. The results are presented in terms of comparisons among U. S. shipyards and between U. S. and foreign shipyards.

FOREWORD

This report, Technology Survey of Major U. S. Shipyards - 1978, is organized as follows:

- Chapter I. Introduction -- Sets forth the circumstances that caused the survey to be made and what it should accomplish, along with its limitations.

- Chapter II. Survey Procedure -- Describes how the survey was conducted in the United States and abroad, what shipbuilding activities were covered and how technology was measured.

- Chapter III. Comparisons and Analyses -- Puts in perspective over 2000 technology level determinant made in 13 U. S. shipyards and 16 comparable foreign shipyards. First, they are treated in aggregate form. Second, they are treated in a more detailed but selective manner to emphasize the most important shipbuilding operations, highlighting areas where U. S. shipbuilding technology is high and low.

- Chapter IV. Basic Data -- Consists of a series of tables which present all of the technology level determinations developed during the survey, in three different ways. Chapter III is based on these data.

- Chapter V. Summary -- Sets forth the highlights of the survey, including comnents from A & P Appledore (London) Ltd., who developed the technology level standards and surveyed the foreign shipyards.

The Maritime Administration and Marine Equipment Leasing, Inc. wish to acknowledge the substantial contributions made to this survey by A & P Appledore (London) Ltd. and the U. S. shipbuilders whose complete cooperation made the survey possible.

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1. INTRODUCTION

I INTRODUCTION

At the end of World War II, the United States had the largest and most productive shipbuilding industry in the world. During the past 30 years, this industry has contracted to a fraction of its former size and has only in recent years made substantial investments in new facilities. On the other hand, foreign shipbuilders, notably Japanese, have invested billions of dollars since WWII in new facilities and can now produce merchant ships in a much shorter time and with substantially fewer manhours than are required in the United States.

1. U.S. SHIPYARDS STILL LAG BEHIND LARGE PRODUCTIVE SHIPYARDS IN JAPAN AND EUROPE

The U.S. shipyards have gone through a major organizational and technological change in the past 10 years. The United States Navy, being concerned with increasing shipbuilding costs, changed its acquisition policies to promote economies of scale in its multibillion dollar program and, in so doing, attracted industrial conglomerates into the shipbuilding business. The Maritime Administration of the Department of Commerce has also encouraged standard ship design concepts to promote economies through multi-ship construction programs. At the present time, all but two of

our major shipyards are owned by large parent corporations. Primarily as a result of this new ownership, over a billion dollars have been spent on new facilities and the modernization of existing shipyards since 1970.

In the area of construction of nuclear and conventionally powered naval combatant ships, the U.S. is without peer in the free world. With respect to construction of large merchant ships, however, United States shipyards still lag behind the large productive shipyards in Europe and Japan.

In spite of substantial improvements that have been made, overall shipyard labor productivity in the U.S. has declined. U.S. shipyards have placed this deterioration in productivity over the last 10 years to be from a minimum of 15% to as much as 35%. This loss in productivity, though not attributable to lack of facility improvement, can be compensated for and improved if facilities, working environment, planning and other factors are improved.

2. THE MARITIME ADMINISTRATION IS ACTIVE IN PROMOTING PROGRAMS WHICH WILL ENHANCE SHIPYARD PRODUCTIVITY

In an effort to improve the productivity of the U.S. shipbuilding industry the Maritime Administration initiated the National Shipbuilding Research Program which since 1971 has sponsored

and jointly funded many R&D projects with a view toward improving the competitiveness of the U.S. shipbuilding industry. However, there has not been a uniform industry-wide evaluation of the technology being applied to all phases of shipbuilding with a view toward identifying industry-wide needs. The R&D programs to date have usually dealt with development of specific equipments and procedures where deficiencies have tended to be apparent.

In 1975, the British government conducted a technology survey of all United Kingdom shipyards in connection with the nationalization of the industry. After seeing the procedure used, the Maritime Administration concluded that a similar survey of major U.S. shipyards would be useful.

In May 1978, the Maritime Administration contracted for an assessment of the level of technology now being employed by major U.S. shipyards, as compared to the best comparable foreign shipyards. The procedure used to make this assessment was the same as that used in the U.K. which had been developed by a prominent British engineering firm, A&P Appledore (London) Ltd. (APA).

3. THE PURPOSE OF THIS REPORT IS TO ENCOURAGE A STRUCTURED AND ANALYTICAL EXAMINATION OF THE SHIPBUILDING PROCESS IN THE UNITED STATES

This report identifies U.S. ship construction operations and procedures that are lagging behind their foreign counterparts. It

is hoped that this survey will provide guidance in two ways.

(1) Encourage Individual Shipyards To Examine In Depth Areas Where They Are Using Low Level Technology

First, it is hoped this survey will encourage U.S. shipbuilding management to look at their operations and examine in more depth areas where the difference between U.S. and foreign technology is greatest. By giving special attention to those areas (elements) that are labor intensive or labor sensitive, this study could be most helpful in supporting long range shipyard improvement plans or proposals for government participation.

(2) This Study Can Also Serve As A Baseline To The Government For Detemining What Shipyard Improvement Programs It Should Support

Second, since this survey covers such a broad spectrum of shipbuilding operations and procedures it is possible to look at the value of one operation in relation to another to determine which operation, if improved, would have the greatest impact upon productivity.

By establishing a baseline in accordance with well defined standards a future survey could measure the effectiveness of improvement programs and identify additional advances in technology.

(3) This Report Deals With Facilities, Equipment and Systems, But Does Not Measure Motivation, Management Or Effort

Shipyard productivity depends upon a combination of many factors. The facilities, tools and procedures covered in this survey are most important, but they are only as good as the people who manage and operate them.

This report only identifies the levels of technology being used. The decision by a shipyard to use more advanced technology would depend upon an economic feasibility analysis taking into account the market and the characteristics of the individual shipyard.

II. SURVEY PROCEDURE

SURVEY PROCEDURE

The evaluation system used for this technology survey was developed by A&P Appledore (London) Ltd. (APA). The survey was conducted by Marine Equipment Leasing, Inc. (MEL).

1. THE SHIPBUILDING TECHNOLOGY SURVEY CONCEPT HAS BEEN USED INTERNATIONALLY

The system for evaluating shipbuilding technology was developed in 1975 and was first used in an extensive study prepared for the British Government shortly before it nationalized its shipbuilding industry. The purpose of the U.K. study was to obtain a commonly based, objective appreciation of the quality and quantity of the hardware and the associated methods and technology being used in each shipyard. Since that time, the system has been formally applied in Canada, France, Egypt and India.

(1) The Shipbuilding Categories Considered Cover The Full Range of Shipyard Operations

Information on the technology and methods employed in each shipyard is collected by way of a survey of these principal operational categories:

- Steelwork Production
- Outfit Production and Stores

Figure II-1

E L E M E N T S   S U R V E Y E D

A: STEELWORK PRODUCTION

A1 PLATE STOCKYARD AND TREATMENT
A2 STIFFENER STOCKYARD AND TREATMENT
A3 PLATE CUTTING
A4 STIFFENER CUTTING
A5 PLATE AND STIFFENER FORMING
A6 SUB-ASSEMBLY
A7 FLAT UNIT ASSEMBLY
A8 CURVED AND CORRUGATED UNIT ASSEMBLY
A9 3-D UNIT ASSEMBLY
A10 SUPERSTRUCTURE UNIT ASSEMBLY
All OUTFIT STEELWORK

B: OUTFIT PRODUCTION AND STORES

B1 PIPEWORK
B2 ENGINEERING/MACHINE SHOP
B3 BLACKSMITHS
B4 SHEETMETAL WORK
B5 WOODWORKING/JOINER SHOP
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- Other Pre-erection Activities
- Ship Construction and Outfit Installation
- Layout and Materials Handling
- Environment and Amenities
- Design, Drafting, Production Engineering and Lofting
- Organization and Operating Systems.

These categories have been broken down into seventy-two (72) elements as shown in Figure II-1, preceding page.

Each of the seventy-two elements covers a discrete shipbuilding operation or procedure. To illustrate, the following are examples of the descriptions of several elements and the points evaluated.

A1. PLATE STOCKYARD AND TREATMENT

Description: The storage, handling, treatment and control of plate from receipt to delivery to the cutting area.

Points Evaluated: Method of storage, handling, treatment, manning, control.

A3. PLATE CUTTING

Description: Cutting by all means large rectangular and non-rectangular plates, large and small internals, floors, longitudinal, webs, etc.

Points Evaluated: Marking, handling, cuttings accuracy.

A7. FLAT UNIT ASSEMBLY

Description: This includes the welding together of flat plates to form flat sections of shell, deck, bulkhead, tank top, etc. It includes attachment of stiffeners, floors, webs and longitudinal.

Points Evaluated: Workstation definition, materials handling, material positioning, welding, fairing, major unit build up, storage.

Appendix A, DESCRIPTION OF THE 72 SHIPBUILDING ELEMENTS, contains the complete description of each of the seventy-two elements in the form shown above. It is noted that two of the elements, B5 and DIO, cover wood working/joiner work. Since U.S. ships contain virtually no finished wood products, these two elements were not given level assignments in the U.S. shipyard survey. Therefore, only 70 of the elements have been included in the comparisons.

(2) Standards Have Been Established To Identify Four Levels Of Shipbuilding Technology Which Are Applicable Worldwide

A four point scale of reference is used during the

examination of technology, methods and operating systems. In simple terms:

Level 1 - Indicates basic or low technology and characterizes the shipyard of the fifties and early sixties.

Level 2 - Relates to the medium technology shipyard of the sixties.

Level 3 - Reflects good practice in the early seventies.

Level 4 - Typifies a high output, advanced technology shipyard.

A descriptive set of standards for each of the seventy-two elements has been prepared. These standards consist of examples of methods and practices which typify each of the four levels of technology for each element. The surveyor is thereby able to assign a "level of technology" to each aspect of shipyard operation which is studied. During the survey, the "closest" whole level number is marked and comnents peculiar to the shipyard and element being studied are recorded.

Eight samples of the shipbuilding technology standards used in the survey are shown in Appendix B, <u>SAMPLE LEVEL CRITERIA FOR SHIPBUILDING TECHNOLOGY</u>.

Al - Plate Stockyard and Treatment

B1 - Pipework (shop)

C3 - Pre-erection Outfitting

D5 - Staging and Access (ship)

E2 - Materials Handling

Fl - General Environmental Protection

G7 - Design for Production

H2 - Contract Scheduling.

These sheets give examples of methods and practices which typify each of the four levels of technology. Their purpose is to give the survey team a scale of reference. In this way, it is possible to make world-wide comparisons on a consistent basis is and also to vary the teams from shipyard to shipyard and still obtain valid and comparable results.

(3) This Survey Compares Each U.S. Shipyard With Four Comparable Foreign Shipyards

In order to give the survey of U.S. shipyards relative meaning in a worldwide sense, it was decided that each shipyard would be compared with four of the best comparable foreign shipyards. The determination to limit the comparison to four shipyards was based on the need to keep the survey within a reasonable budget and time span. It was further decided, in order to assure a diversified geographical distribution, to limit the number of comparable shipyards in any one country in a single comparison to two. The final ground rule was that at least one Japanese shipyard should be in each comparison because of Japan’s preeminence in world shipbuilding.

2. THE SURVEY PROCESS INVOLVED THE USE OF TWO SURVEY TEAMS

In order to survey 13 U.S. shipyards in the alloted time two survey teams were required. The earlier surveys of foreign shipyards also involved different surveyors. All surveyors, however, used the same standards and essentially the same survey techniques.

(1) To Assure Consistency and Comparability Of Data. Surveyor Training And Cross-Checking Of Data Was Required

During the week of June 5, 1978, two senior members of the APA staff conducted a workshop for the six MEL surveyors on survey content and procedure. The workshop covered in detail what was included in each of the 72 elements and a discussion of the four technology levels for each element. This workshop and the ensuing exchange of views enabled the U.S. surveyors to be on the same "wavelength" as their British counterparts.

The second step taken by MEL to assure consistency and comparability of data was to design data sheets for collecting data. Appendix C, EXAMPLES OF CORRECTED SURVEY NOTES, is a reproduction of actual data sheets for the eight elements shown in Appendix B.

The third step took place after the survey when all the surveyors met and exchanged annotated data sheets. Initially, each surveyor assigned a technology level to each element he

surveyed. When the data sheets were exchanged with the counterpart surveyor on the other team, the level assignments were withheld and the counterpart surveyor read the notes and made his own level assignments. Then, the two surveyors compared notes and reached agreement on the level assignments. This was done between the three pairs of surveyors that made up the two teams. It turned out that the surveyors were in agreement at least 90% of the time. This is very good considering that levels are stated in whole numbers and there are a number of borderline cases, e.g., closer to 2 or closer to 3.

The fourth and final step took place in England. During the process of comparing U.S. shipyards with their foreign counterparts, each level assignment was reviewed using the surveyors' notes with the same APA staff engineers who conducted the workshop so as to assure consistency with the APA survey of the foreign shipyards.

(2) The Thirteen Major Shipyards Surveyed Have Built Some Of The Most Complex Ships In The World

The selection of the U.S. shipyards to be surveyed was based primarily on size, employment, and product. Since the survey included foreign shipyards building primarily for deep-sea commercial service with some naval construction, the largest of the U.S. shipyards building for this service

were selected. These shipyards are now building over a broad span of complexity and ship size, from a nuclear powered aircraft carrier and submarines to gas turbine powered frigates and from commercial ships ranging from a 10,000 DWT tanker to 395,000 DWT ULCCs and LNG ships. Figure II-2, following Page shows the location and names of the shipyards surveyed. One large shipyard, General Dynamics, Groton, which is building nuclear powered submarines exclusively, was excluded. Included in the survey, as part of the General Dynamics, Quincy, report, is the General Dynamics, Charleston, SC, liquid natural gas (LNG) sphere manufacturing facility.

The U.S. Shipyard Technology Survey took place during the period July 17 through August 15, 1978. The shipyards surveyed were as follows:

Shipyard	Survey Dates
Bath Iron Works Bath, ME	17-18 July 1978
General Dynamics Quincy, MA	20-21 July 1978
General Dynamics Charleston, SC	3 August 1978
Seatrain Shipbuilding Brooklyn, NY	24-26 July 1978
Sun Shipbuilding Chester, PA	27-28 July 1978
Bethlehem Steel Sparrows Point, MD	31 July-1 August 1978
Newport News SB & DD Newport News, VA	7-10 August 1978
Ingalls Shipbuilding Div. Pascagoula, MS	25-28 July 1978

SHIPYARDS SURVEYED

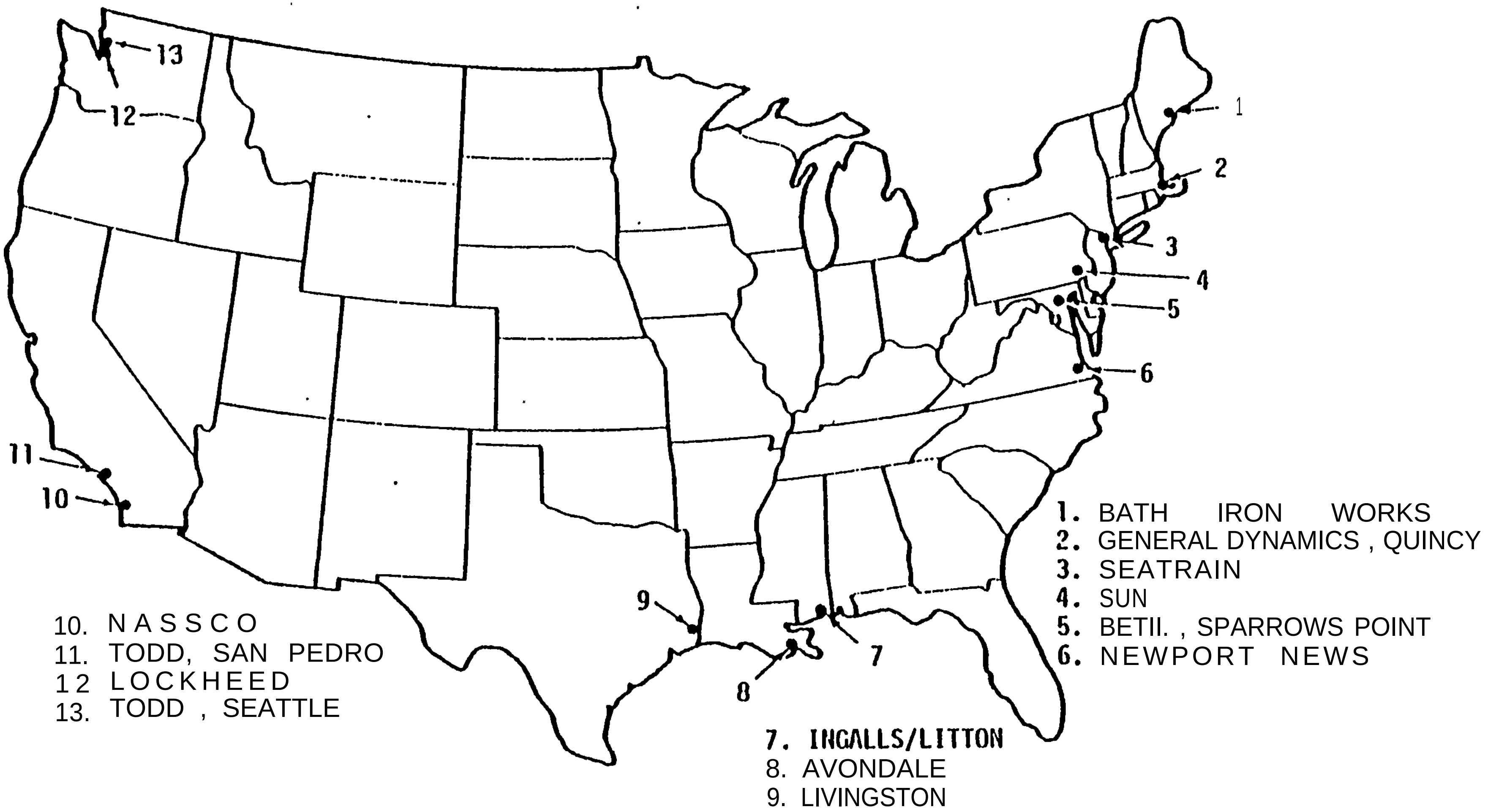


Figure II-2

Shipyard	Survey Dates
Avondale Shipyard New Orleans, LA	17-19 July 1978
Livingston Shipbuilding Orange, TX	31 July-1 August 1978
National Steel & SB San Diego, CA	3-4 August 1978
Todd Shipyards San Pedro, CA	7-8 August 1978
Todd Shipyards Seattle, WA	10-11 August 1978
Lockheed Shipbuilding Seattle, WA	14-15 August 1978

The two survey teams visited the U. S. shipyards simultaneously. One team surveyed the East Coast from Bath, Maine to Charleston, South Carolina. The other team surveyed the Gulf and Pacific coasts.

Each team was made up of three surveyors with each surveyor assigned a specific group of elements to survey. A typical survey schedule is shown in Figure II-3, following page. This schedule and a description of the survey elements shown in Appendix A were sent to the shipyards in advance of the surveys along with a request that a knowledgeable guide be designated to accompany each surveyor and arrange that he talk to the responsible people in each area. Each surveyor took notes on each of his assigned elements using the prepared data sheets and also composed summary statements which were addressed to the standards for each element. Examples of the note-taking and the summary statements are shown in Appendix C.

Figure II-3

SURVEY SCHEDULE

	Surveyor #l	Surveyor #2	Surveyor #3
Day 1 A.M.	Introduction Yard Tour	Introduction Yard Tour Layout & Environ. El - E4	Introduction Yard Tour
Day 1 P.M.	Steelwork Prod. Al - A7	Outfit Prod. & Stores B1 - B6	Yard Background Technical Info. G1 - G3
Day 2 A.M.	A8 - All Pre-erection c1 - C4	B7 -B11 D6 - D7	G4 - G9 Org. & Op. Systems H1 - H4
Day 2 P.M.	C5 - C6 Ship Const.	D8 - D14 Amenities FI - F3	H5 - H13

Upon completion of the note-taking, the notes and summary statements were sent back to the shipyard for review and comment. After the comments were reviewed, the summary statements were revised, if necessary, and the level of technology affirmed or changed.

(3) Sixteen Major Foreign Shipyards Were Selected For Comparison With U.S. Shipyards

APA was supplied with copies of the shipyard survey notes together with a brief description of each U.S. shipyard surveyed. These descriptions included:

- o past work experience
- o current work experience
- o principal facilities
- o maximum ship size
- o site area
- o labor force.

These U.S. shipyard histories and characteristics are in Appendix D, UNITED STATES SHIPYARD HISTORIES AND DESCRIPTIONS.

On receipt of this information, APA reviewed their data on twenty-five leading foreign shipyards in Japan, Germany, France, Denmark, Sweden and in the U.K.

For each U.S. shipyard, a number of foreign shipyards were selected as being appropriate for comparison. The number of foreign shipyards to be compared to each U.S. shipyard was then reduced to four, of which no more than two were in the same country and of which one was in Japan.

The selection of foreign shipyards took into account all the information contained in the descriptions of the U. S. shipyards. During the MEL visit to APA in England, the selection process was fully reviewed in order to ensure that MEL was satisfied that the most advanced comparable shipyards had been selected. Some adjustments were made during the exchange of more detailed information on the U. S. and foreign shipyards.

Appendix E, DESCRIPTIONS OF COMPARABLE FOREIGN SHIPYARDS, contains the summary of the characteristics of the foreign shipyards selected for comparison.

For all the foreign shipyards, levels of technology have been assigned in accordance with the scale of reference defined in the APA shipbuilding technology survey technique. In half of the shipyards, APA has conducted a full survey of facilities, equipment, technology and methods. For the remaining shipyards, senior APA staff members have spent a minimum of two man weeks in each shipyard during the past three years. A considerable number of APA personnel have, therefore, been involved in assigning the levels of technology to the selected shipyards.

In order to maintain the confidence of past clients and to secure continued exchange of information with leading foreign shipyards, APA is unable to disclose the names of the shipyards for publication.

In selecting comparable foreign shipyards, the following

principal selection criteria were used:

Work experience	-past ten years
Work experience	-current
Maximum ship length	-feet
Shipbuilding employment	-
Size	-acres
Type of shipyard	-new/redeveloped

Work experience and shipyard type categories are coded as follows:

Work experience	A simple commercial ships
	B complex commercial ships
	C simple naval ships
	D combatant ships
Shipyard type	L underwent limited redevelopment
	M underwent major redevelopment
	N new/greenfield shipyard

In Table II-1, following page, is a display of these criteria for the thirteen U. S. and sixteen foreign shipyards covered by the survey.

The process for making the actual selection of comparable foreign shipyards consisted of preparing thirteen selection sheets like Table II-2, page II-17, one for each U. S. shipyard, and including the foreign shipyards whose characteristics and products most closely resembled the U. S. shipyard. In this

CRITERIA FOR SELECTION OF COMPARABLE SHIPYARDS

U.S. Shipyard	Work Experience Past	Work Experience Current	Max. Length Ship	Emplment Shpbldg	Size Acres Shpbldg	Yard Type Calog.	New Yard / Redeveloped Yard Highlights
Bath Iron Works	A, B, D	B, D	700	3300	02	L	Redev. since 1970 - outfitting pier, ways mod., 220 ton crane
Gen. Dynamics, Qu.	B, C	B	930	6300	172	M	Redev. since 1970 - steel cut & fab., basin sphere plant 1200 ton cr
Seatrain	A	A	109-1	2100	Go	M	Redev. since 1970 - steel cut & fab., paint facil., 4 x 200 ton cr
Sun	A, B	A, B	1100	3000	160	M	Redev. since 1970 - constr. & launch sectional dock, 2 x 250 ton cr
Bethlehem, Sp. Pt.	A	A, B, C	1200	3260	142		Redev. since 1968 - steel cut & fab, building basin, 4 x 200 ton cr
Newport News	A, B, D	A, B, D	1000	22000	250	N/M	New comm. yard since 1973 - steel fab., building basin, 1000 ton cr
Litton/Ingalls	B, D	D	800	10500	400	M	New yard since 1968 - unique launching system
Avondale	A, B, D	A, B, C	1050	4300	210	M	Redev. since 1970 - constr. & launch sys., paint fac., 600 ton cr
Levingston	A, B	A, B	700	1700	80	L	N.C. steel cutting
National Steel	A, B, C	A, C	980	5500	145	M	Redev. since 1970 - enlarged ways, new basin, 175 ton cr
Todd, Los Angeles	A, D	D	600	2000	60	L	Redev. since 1975 - enlarged ways, 2 x 175 ton cr
Todd, Seattle	A, B, D	D	550	1000	35	L	N.C. cutting machine
Lockheed	A, B, C	C	700	2500	100	L	Redev. since 1965 - way, N.C. cutting, steel fab., 50 ton cr

Foreign Shipyard	Work Experience Past	Work Experience Current	Max. Length Ship	Emplment Shpbldg	Size Acres Shpbldg	Yard Type Calog.	New Yard / Redeveloped Yard Highlights
Yard G	A	A, B	1360	5700	210	N	New 1950 - 700,000 ton dock, 1,000 ton cr added late 1960's
Yard N	A, B, D	B, D	1000	5400	100	M	Redev. late 1970's - all areas (extensive)
Yard H	A, D	D	1150	3600	40	M	Redev. early 1970's - steel and outfit shops, 2 x 180 ton cr
Yard P	A	A	860	1600	45	M	Redev. mid 1970's - new shipyard built around existing dock
Yard J	A, B	A, B	1500	6500	170	M	Redev. late 1960's - all areas (extensive)
Yard D	A, B	A, B	1170	5900	90	M	Redev. late 1960's/early 1970's - dock and cranage
Yard M	A, B, C	A, B, D	1020	5500	120	L	Improved early 1960's
Yard C	A, B, C, D	A, B, C, D	850	2600	50	L	Gradual redev. within constraints of site
Yard R	A, B, D	B, D	1000	6000	100	M	Redev. within constraints of site - most areas
Yard F	A	A, B	1500 +	3000	200	N	New yard mid 1970's - high steel throughput, high technology
Yard B	A, B, D	A, B	1000	6000	250	M	Redev. from 1968 - steel cutting & fab., dock, 2 x 840 ton cr
Yard K	A, B	A, B	1100	3900	65	L	Redev. early 1970's - steel cutting & fab., berth cranes
Yard E	B, C, D	B, C, D	600	3500	35	L	Gradual improvements over past twenty years
Yard A	A, B	A, B	1300	3900	95	M	Redev. early 1960's - very substantial with subseq. improvements
Yard L	A	A, B	1000	3500	250	N	New mid 1960's - extrusion system, covered work
Yard S	A, B, D	A, B, D	1320	6100	200	M	Major improvements over twenty years - high technology

TABLE II-1

TABLE II-2

SELECTION OF COMPARABLE SHIPYARDS

Criteria	U.S. Shipyard	Foreign Shipyards Yard C	Yard E	Yard N	Yard M
Work Experience					
Past 10 years	A,B,D	A,B,C,D	B,C,D	A,B,D	A,B,C
Current	B,D	A,B,C,D	B,C,D	B,D	A,B,D
Maximum Ship Length (Feet)	700	850	680	1000	1020
Employment	3300	2600	2500	5400	5500
Size (Acres)	92	50	35	100	120
Shipyard Type (New or Re-developed)	L	L	L	M	L

Discussion

There are five foreign shipyards roughly comparable to this U.S. Shipyard. One shipyard which emphasizes steel throughput and which has less complex ship capability was dropped.

illustration, a U.S. shipyard was compared to foreign shipyards C, E, N and M. Appendix F, COMPARABLE FOREIGN SHIPYARD SELECTION SHEETS, contains all thirteen of the selection sheets similar to Table II-2.

The geographic distribution of comparable shipyards is shown in Table II-3, following page.

Table II-4, page II-20, shows the specific foreign shipyards (by code letter) compared to each of the thirteen U.S. shipyards. Appendix E gives a description of each foreign shipyard.

(4) Survey Reports on Individual Shipyards Show the Technology Level Comparison Within the U.S. and With Four of the Best Comparable Foreign Shipyards

Upon the completion of the U.S. shipyard survey and the comparisons made with the foreign shipyards, an individual shipyard report was made on each U.S. shipyard containing the information contained in Figure II-4, page II-21.

Each U.S. shipyard was given a table comparing its technology levels with the other U.S. shipyards. Figure II-5, page II-22, shows how this table was set up. The form of the comparison between each U.S. shipyard and the four comparable foreign shipyards is also shown in Figure II-5.

The bulk of the shipyard report consisted of the “SUMMARY EVALUATION OF SURVEY ELEMENTS” for the 70 shipbuilding elements a sample of which is included in Figure II-6, page II-23.

TABLE II-3

GEOGRAPHICAL DISTRIBUTION OF FOREIGN SHIPYARDS COMPARED TO U.S. SHIPYARDS

Shipyard Name--U.S.	U.K. Yards	Japan Yards	German Yards	Danish Yards	Swedish Yards	French Yards
Bath Iron Works Bath, ME	2	1	1			
General Dynamics Quincy, MA	1	1			1	1
Seatrain Shipbuilding Brooklyn, NY	1	1		1	1	
Sun Shipbuilding Chester, PA	1	1		1		1
Bethlehem'Steel Sparrows Point, MD	2	1		1		
Newport News SB & DD Newport News, VA	1	1			1	1
Avondale Shipyard New Orleans, LA	1	1			1	1
Ingalls Shipbuilding Division Pascagoula, MS	1	1			1	1
Livingston Shipbuilding Orange, TX	2	1	1			
National Steel & SB San Diego, CA	1	1		1		
Todd Shipyards San Pedro, CA	1	1	1			
Todd Shipyards Seattle, WA	2	1	1			
Lockheed Shipbuilding Seattle, WA	2	1	1			

TABLE II-4

COMPARATIVE FOREIGN SHIPYARDS

Shipyard Name--U.S.	Foreign Shipyards			
Bath Iron Works Bath, ME	N	E	C	M
General Dynamics Quincy, MA	B	R	J	S
Seatrain Shipbuilding Brooklyn, NY	R	P	L	G
Sun Shipbuilding Chester, PA	A	R	G	D
Bethlehem Steel Sparrows Point, MD	H	P	R	G
Newport News SB & DD Newport News, VA	B	F	S	J
Avondale Shipyard New Orleans, LA	A	R	D	L
Ingalls Shipbuilding Division Pascagoula, MS	B	F	J	S
Livingston Shipbuilding Orange, TX	E	A	M	C
National Steel & SB San Diego, CA	G	H	L	R
Todd Shipyards San Pedro, CA	N	C	D	M
Todd Shipyards Seattle, WA	K	C	E	M
Lockheed Shipbuilding Seattle, WA	M	K	C	N

I N D I V I D U A L   S H I P Y A R D   R E P O R T

T A B L E   O F   C O N T E N T S

Figure II-4

C O M P A R I S O N S

W I T H U.S. S H I P Y A R D S

DESIGN, DRAFTING, PRODUCTION ENGINEERING AND LOFTING	SPECIFIC U.S. SHIPYARD	U.S. SHIPYARDS				
		AVG.	NO. AT LEVEL			
			1	2	3	4
G 1 SHIP DESIGN	3	2.6	2	4	4	3
G 2 STEELWORK DRAWING PRESENTATION	3	2.7	1	4	6	2

W I T H F O R E I G N S H I P Y A R D S

DESIGN, DRAFTING, PRODUCTION ENGINEERING AND LOFTING	SPECIFIC U.S. SHIPYARD	FOREIGN SHIPYARD LEVEL				
		AVG.	SHIPYARD			
			H	P	R	G
G 1 SHIP DESIGN	3	3.5	3	3	4	4
G 2 STEELWORK DRAWING PRESENTATION	3	3.2	3	3	3	4

Figure II-5

Figure II-6

SUMMARY EVALUATION OF SURVEY ELEMENTS

A6. SUB-ASSEMBLY

Description: Assembly of parts of a main unit. It will include putting face plates on webs, installing brackets, stiffeners on floors, longitudinal, foundations, etc.

Points Evaluated: Workstation definition, material handling, material marking, jigs, welding, fairing, storage, material flow.

Summary Evaluation: Work is carried out in "space available" areas within the fabrication area. Pieces are pre-marked, welding is by manual MIG sets. Some reusable jigs are used. Material flow is logical and the storage area is adequate.

A4. STIFFENER CUTTING

Description: Cutting by all means, e.g., angles, H beams, channels, I beams.

Points Evaluated: Marking, handling, cutting, accuracy.

Summary Evaluation: Marking of stiffeners is done manually. Handling is by bridge crane with hand clamp and also forklift attachment. Cutting is done manually and with a universal steel worker--some minor cold shearing.

A5. PLATE AND STIFFENER FORMING

Description: The process used to effect single or double curvature.

Points Evaluated: Forming process, technical information transfer, handling, accuracy.

Summary Evaluation: Cold bending of plates and stiffeners is controlled by use of templates. Handling is done by magnetic and hand clamp bridge cranes.

(5) The Individual Shipyard Reports Identify Specific Shipbuilding Operations Where Technology is Low, Thus Suggesting Areas for In-depth Analysis by Shipyard Management

The purpose of the individual shipyard reports is to give shipyard managers an unbiased appraisal of their shipyard over a broad spectrum of operations, and to give them a picture of how they compare with other shipyards in the U. S. and four of the best comparable foreign shipyards according to internationally acceptable standards. The comparisons with four comparable foreign shipyards and with other U. S. shipyards contribute to this appraisal by showing where other shipyards have given the greatest emphasis *in* improving their technology. Additionally, an evaluation of technology levels assigned each element can be made on an absolute basis by comparing the level assignments with the level descriptions.

While the individual shipyard reports contain a wealth of information on technology levels, they do not contain information on organizational efficiency, employee motivation and other factors which greatly affect a shipyard's productivity. Also, they do not contain information on the economic feasibility of introducing methods, practices or equipment needed to raise technology levels. Rather, economic analysis is considered to be in the province of each shipyard where knowledge of all pertinent factors is most readily available.

It is hoped that top management will look at their operations where the level of technology is low and make an in-depth analysis to see if introducing more advanced technology would be economically feasible.

III. COMPARISONS AND ANALYSES

III COMPARISONS AND ANALYSES

The rationale underlying the selection of shipyards to be compared and the basic technology level data are presented in Chapters II and IV, respectively. In this Chapter, comparisons and analyses are made. The approach is to go from the broad to the detail level, from the eight categories to the 70 elements. More specifically:

- The average technology levels of the U.S. and foreign shipyards for each of the eight categories are presented in four different ways to provide a broad perspective of the differences found.
- Certain of the 70 elements are identified as critical and are presented in some detail.
- Areas in which the U.S. shipyards measure favorably are identified.
- Some of the causes of technology level differences are identified.

1. ON AN OVERALL BASIS, U.S. SHIPYARDS EXHIBIT LOWER TECHNOLOGY LEVELS THAN THE FOREIGN SHIPYARDS

The data developed during this technology survey provide a wealth of detail for comparison and analysis. Over 2000 technology level judgments were recorded together with considerable data on shipyard characteristics and workload. These data have been consolidated to provide a manageable overview of the industry. While recognizing the risk in making such consolidations, it is believed

that they accurately reflect the comparative situation at the time the field survey work was done.

(1) Foreign Shipyards Lead U.S. Shipyards in Six of the Eight Categories Surveyed

As described in Chapter II, the 70 elements to which technology levels were assigned for-each shipyard fall in eight shipbuilding process categories, each containing generally similar items. For example, Steelwork Production, Category A, contains 11 elements ranging from Plate Stockyard and Treatment, Element Al, to Outfit Steelwork, Element All. Figure III-1 was constructed by averaging the technology levels of all U.S. shipyards and all foreign shipyards on all the elements making up each of the eight categories, starting with Steelwork Production, Category A.

TECHNOLOGY LEVELS BY CATEGORY

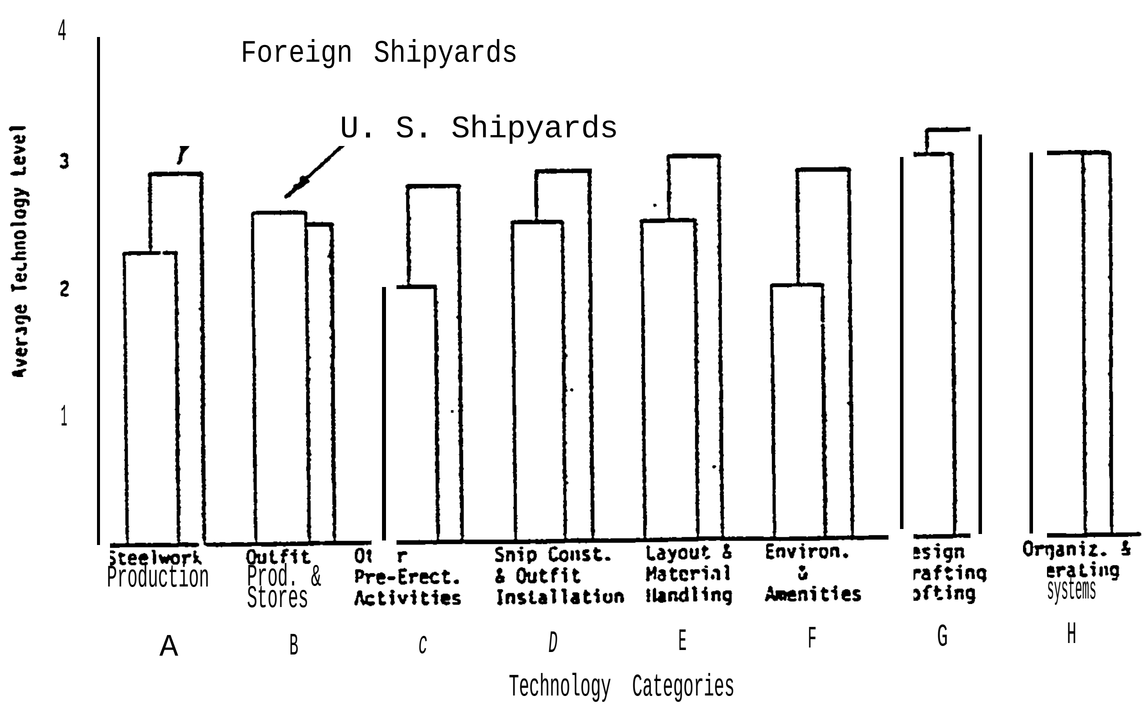


Figure III-1

The U. S. shipyards lead the foreign shipyards only in Category B, Outfit and Production Stores. Average technology levels are the same for Category H, Organization and Operating Systems. For the remaining six categories, U. S. shipyard technology levels are lower on the average, the greatest disparities arising with the Categories C and F, Other Pre-erection Activities, and Environment and Amenities, respectively. This invites closer review of Figure III-1. The first four categories (A-D) cover the technology employed in the “hands-on” manpower intensive part of a shipbuilding project. Two of the remaining four categories primarily concentrate on the work place and working conditions. The last two deal with the engineering and systems elements which direct and control the “hands-on” work. In actual fact, these last four categories are supportive since their purpose is to make it possible for the work force to complete the ship in as short a time as possible with minimum” expenditure of manpower.

The shortfalls in three of the first four categories stem from two broad causes. One concerns facilities and equipment, e.g., covered work places, semi-tandem building berths, heavy lift cranage. The other concerns items which are amenable to solution by thoughtful execution of the elements comprising the last four, and particularly, the last two categories. Examples include the adoption of extensive pre-outfitting practices, construction of modules and improved dimensional control. In a

number of cases, management initiative alone is all that is needed.

(2) The Magnitude of the Differences In the Technology Levels of U. S. and Foreign Shipyards Is Substantial

A second overall view of the technology level differences is presented by Figure III-2.

DISIHBUTION OF TECHNOLOGY LEVEL DIFFERENCES

- U.S. VS FOREIGhl AVERAGES FOR EACH OF 70 ELEMENTS -

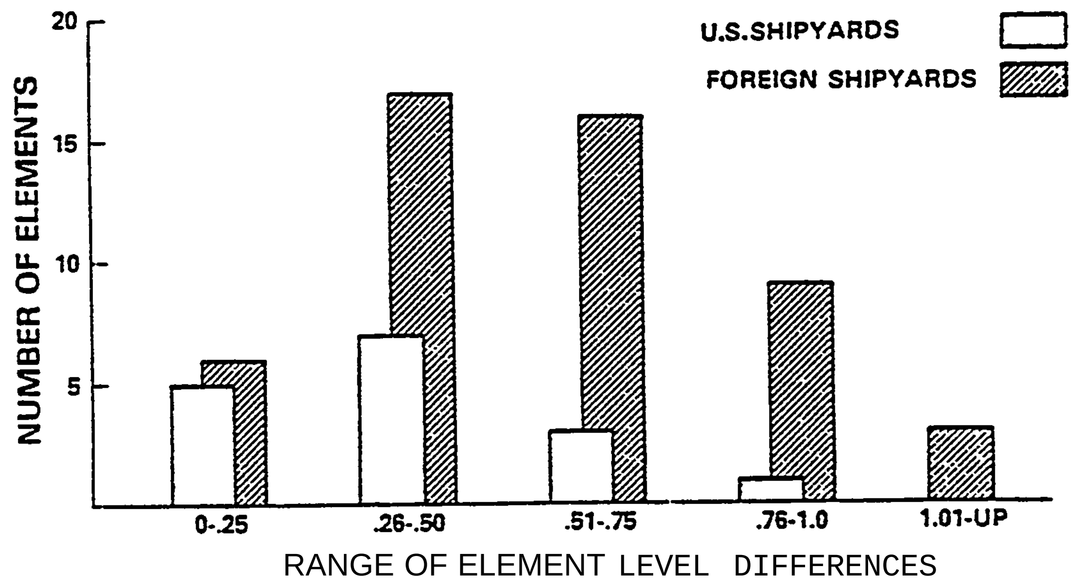


Figure II I-2

Of the 70 elements considered, the foreign shipyards led in 51, the U.S. shipyards in 16. There was a tie on three of the elements. To illustrate the magnitude of the differences in technology levels, five ranges by quarter levels of difference were established. At the low end of the range where there is a difference in technology level of O to .25 levels, the U.S.

shipyards led in five elements while the foreign shipyards led in six. U. S. shipyards led in only one element in the range of .75 to 1.0 levels while foreign shipyards led in nine elements.

Overall, when U. S. shipyards lead, they lead by smaller margins, as can be noted from the bias to the left of the apparent center of gravity of the four U. S. shipyard bars in Figure 111-2, .as compared to the center of the five foreign shipyard bars. Thus, when the foreign shipyards lead, they tend to lead by a substantial amount.

(3) Medium Sized U. S. Shipyards Compared Least Favorably to Their Foreign Counterparts

Early in the assessment of the survey findings, it was noted that the technology levels of the larger shipyards were higher than those of the smaller shipyards. The major U. S. shipyards were divided into three size groups of two, six and five shipyards, large, medium and small, respectively, to test this observation. The criteria used were essentially the same as those described in a previous section of this report which were used to match U. S. shipyards with comparable foreign-shipyards. The foreign shipyards were divided into comparable groups of four, ten and seven shipyards by keeping them with the specific U. S. shipyards with which they are compared

throughout the survey. No foreign shipyard appears more than once in any one group but, because some of the shipyards were used within comparisons with more than one U.S. shipyard, five foreign shipyards appear in two of the size groups.

Figure III-3A compares the average technology level of each large, medium and small U.S. and foreign shipyard in Steelwork Production, Category A.

COMPARISONS OF AVERAGE TECHNOLOGY LEVELS
BY SIZE OF SHIPYARD

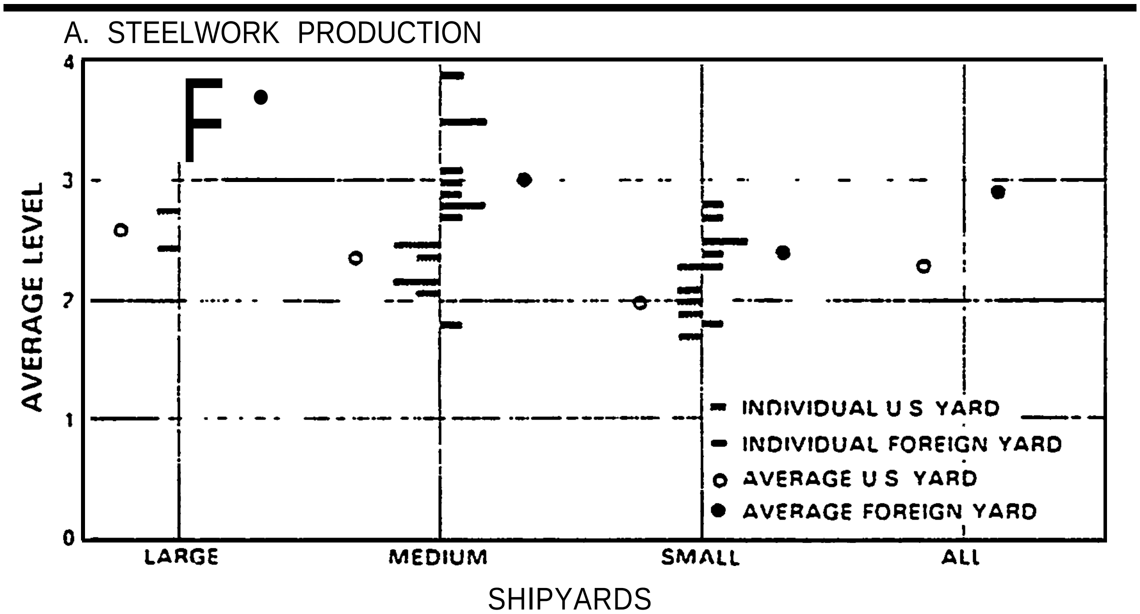


Figure III-3A

In each case, foreign technology is significantly higher.

Also, the average technology level of the highest U.S. shipyard in each size group is below the foreign average for that group, and the ranges barely overlap. Supporting detail at the element level indicates that the U.S. shipyards excel only in Plate Cutting, Element A3. On the other ten elements, the foreign shipyard average technology level is higher.

Figure 111-3B covers Category B, Outfit Production and Stores.

COMPARISONS OF AVERAGE TECHNOLOGY LEVELS

BY SIZE OF SHIPYARD

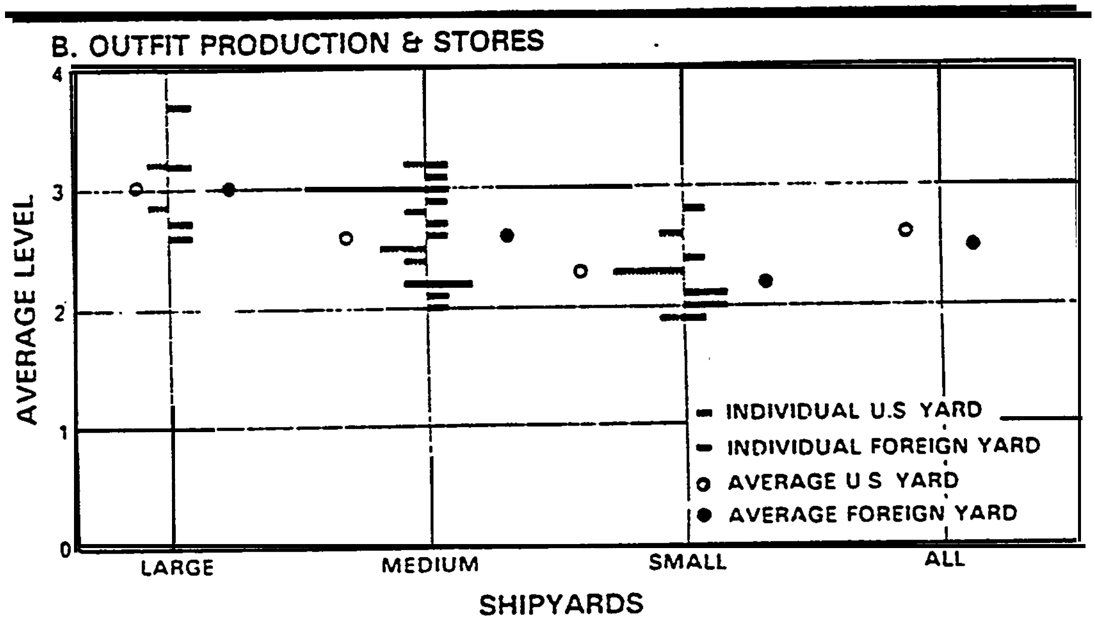


Figure III-3B

In this case, an aggregate of 11 elements, the U.S. overall average is higher. Also, the range between the high and low performance of the shipyards in each size group is

roughly equivalent although there is only one case where the highest U.S. shipyard matches its foreign counterpart in the size group. Throughout this series of figures, it can be noted that technology levels vary with shipyard size, the larger shipyards averaging the highest technology.

Outfit Production and Stores, Category B, is the only category in which the U.S. shipyards enjoy a lead. U.S. and foreign shipyards are equal in Category H, Organization and Operating Systems. While additional facts and analysis would be needed to draw a firm conclusion, it does appear that the high levels reached in these two categories stem at least in part from the facts that many of the U.S. shipyards are involved with Navy work and ship repair work. These kinds of work require more extensive shop support and the Navy work, particularly, requires detailed scheduling and control systems.

Figure III-3C, following page, relates to Other Pre-Erection Activities, Category C. It covers work that traditionally is done on the building berth but, in the high technology shipyards, is done concurrently in numerous units or blocks prior to erection on the berth. The large and medium sized U.S. shipyards are substantially behind in this category which combines five elements. The small U.S. shipyards fare better in relation to their foreign counterparts, but both are low.

COMPARISONS OF AVERAGE TECHNOLOGY LEVELS
BY SIZE OF SHIPYARD

C. OTHER PRE-ERECTION ACTIVITIES

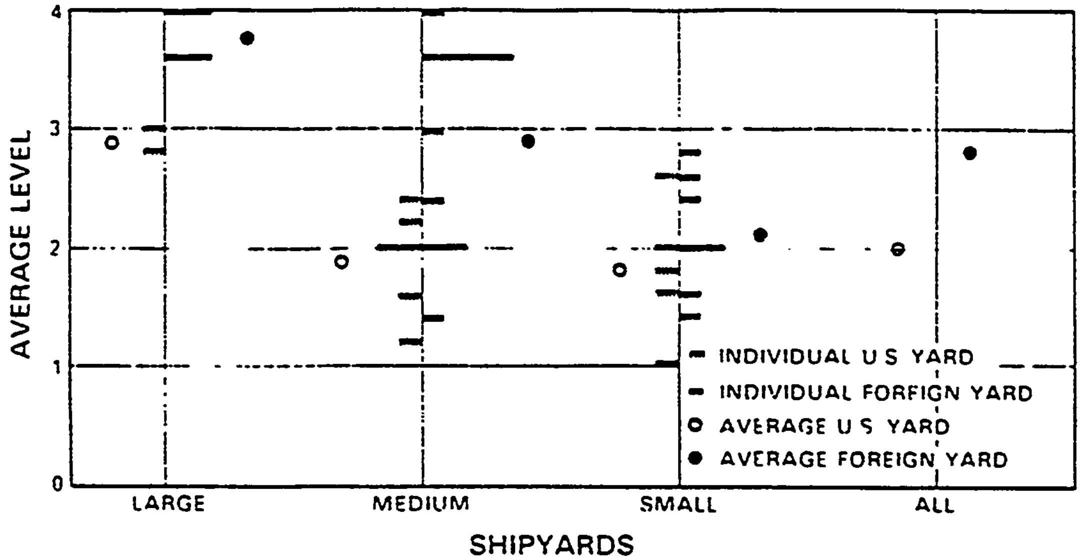


Figure III-3C

More than any other single category, other Pre-Erection Activities, Category C, clearly marks the high technology, modern shipyard. It is not necessary to engage in any of the five elements making up this category in order to build a ship. However, it has been demonstrated that ships can be built in a significantly shorter time period with significantly fewer man days if high technology is achieved on these elements.

It is noted that on the average the medium sized U.S. shipyards are substantially behind their foreign counterparts in this category. This same observation can be made for several of the categories to follow.

Figure III-3D, Ship Construction and Outfit Installation, Category D, covers the work on the building berth and after launch.

COMPARISONS OF AVERAGE TECHNOLOGY LEVELS BY SIZE OF SHIPYARD

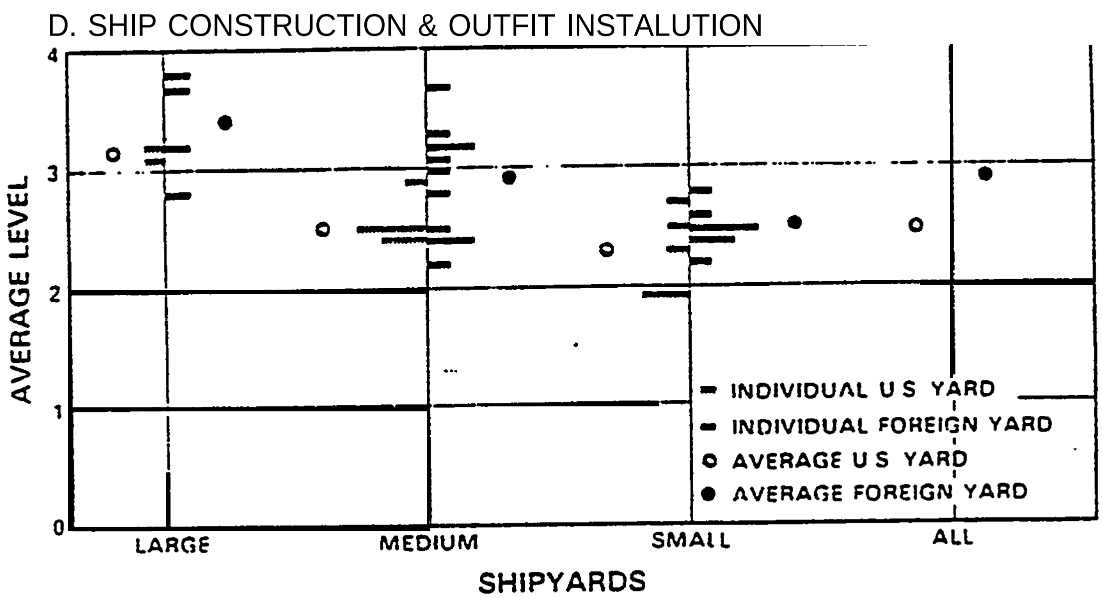


Figure III-30

The large U.S. shipyards have quite high technology in this area and three of the five small shipyards closely match their foreign counterparts. The highest of the medium sized U.S. shipyards matches the foreign shipyard average, with the others well below.

High technology in this category requires efficient fairing and welding, excellent services and well planned and

sequenced installation of outfit. In the very high technology shipyard, the ship is virtually complete upon launch and time on the building berth is very short.

Figure III-3E, Layout and Materials Handling, Category E, contains the averages of just two elements.

COMPARISONS OF AVERAGE TECHNOLOGY LEVELS
BY SIZE OF SHIPYARD

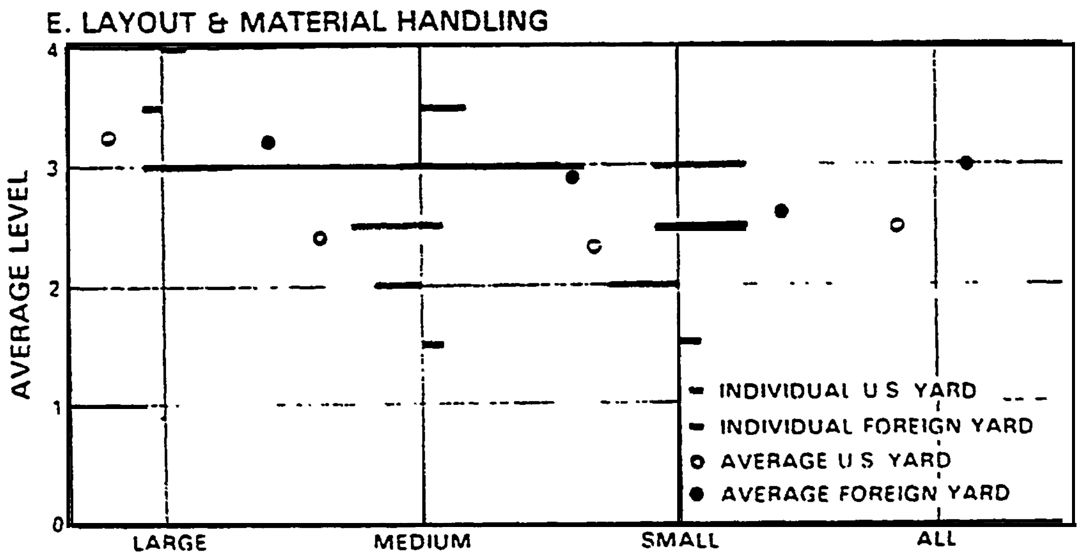


Figure III-3E

In essence, technology Level 4 can be achieved on Element El, Layout and Material Flow, only in a new greenfield shipyard. Dependence upon shops in the adjacent old shipyard results in material flow problems which detract from the optimum. Up-to-date materials handling equipment including conveyors and special purpose manipulating equipment is required

to increase the technology level of Element E2, Materials Handling. Large U.S. shipyards match their foreign counterparts in this category while the technology level averages of the small and medium shipyards fall behind. The number of foreign shipyards at Level 3 in each size group is an indication of extensive modernization efforts.

Figure III-3F applies to Category F, Environment and Amenities.

COMPARISONS OF AVERAGE TECHNOLOGY LEVELS
BY SIZE OF SHIPYARD

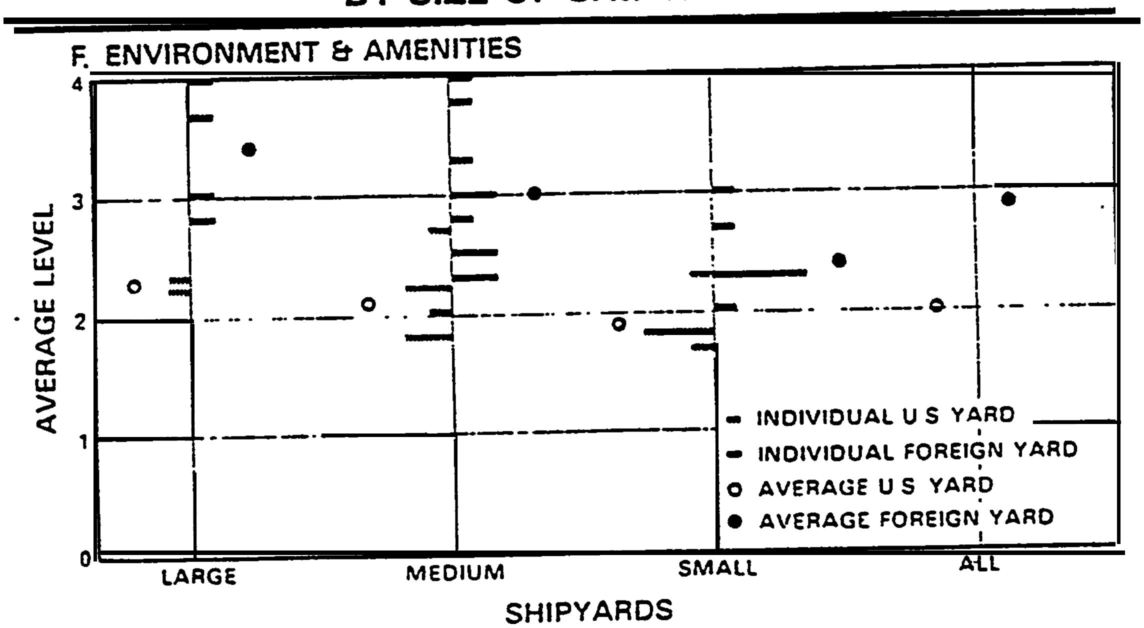


Figure III-3F

The elements in this category relate generally to services and support provided to employees. Some of these elements involve matters which have an impact on productivity.

For example, protection from heat, cold, noise and other aspects of working conditions. Generally, U.S. shipyards do not measure up to the foreign shipyards in these environmental factors. Also, relatively little attention is being paid to access to meals or a decent place to eat them. It is noted that the small foreign shipyards are rather low in this category as well. Improvement in these elements might improve productivity through greater motivation and reduced turnover. This area appears to merit consideration.

Figure III-3G applies to Category G, Design, Drafting Production Engineering and Lofting.

COMPARISONS OF AVERAGE TECHNOLOGY LEVELS
BY SIZE OF SHIPYARD

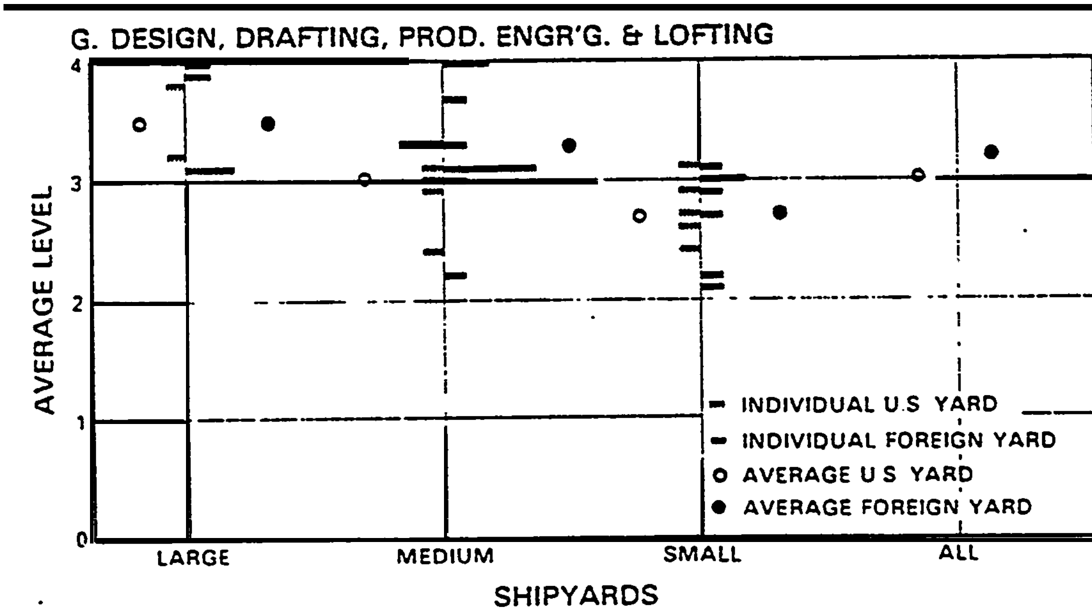


Figure III-3G

U. S. shipyards do quite well in this category with only the medium-sized shipyards falling a little behind. With respect to the design elements, it was found that foreign shipyards do more active marketing of their own designs. Of course, they are not so heavily involved in Navy work which is not marketable. With respect *to* Production Engineering, Element G6, it was found that this function is scattered in several U. S. shipyards and that less attention is being given to the continuing development of assembly, outfitting and erection standards, practices and sequences which serve to shorten construction time and reduce man hours.

Figure III-3H depicts the average technology levels for Category H, Organization and Operating Systems.

COMPARISONS OF AVERAGE TECHNOLOGY LEVELS BY SIZE OF SHIPYARD

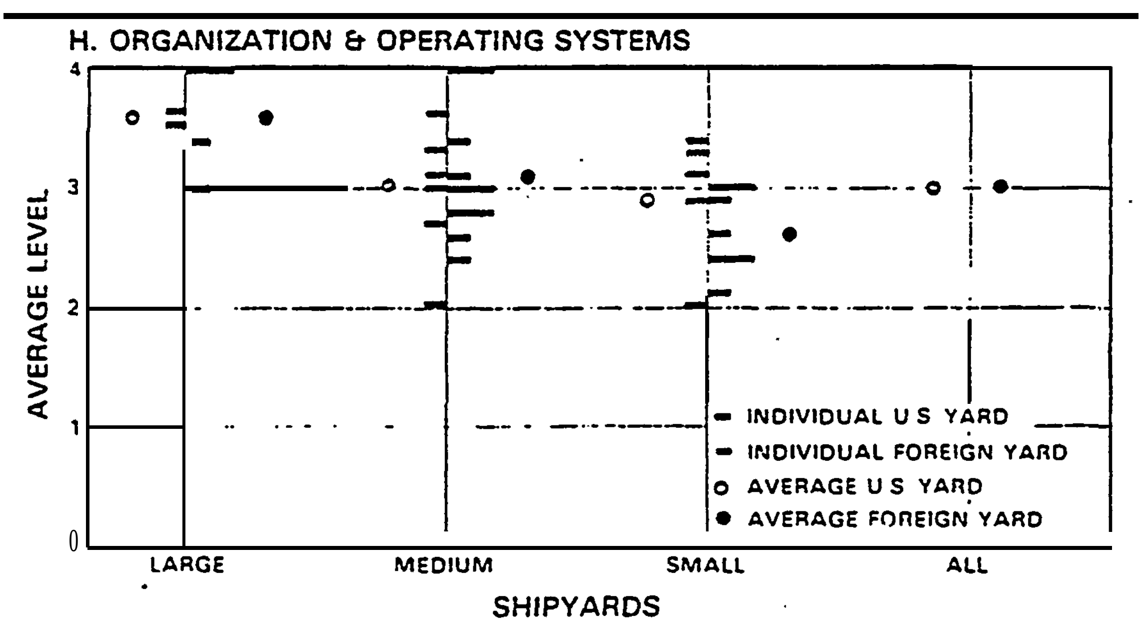


Figure III-3H

The single Organization of Work Element, Element Hl, concerns the flexibility permitted in assigning work to and in supervising the work force. Some of the foreign shipyard managers have considerable flexibility in this regard.

With respect to systems for scheduling and controlling work, the U. S. shipyards are generally well advanced. This certainly stems, in part, from the requirements for certain management controls imposed by Department of Defense Instruction 7000.2, and from the requirements imposed by the complexity of many of the ships built in U. S. shipyards. However, while there was evidence that the systems serve to keep management informed, there was less evidence that the systems were being used by first line supervisors in directing the efforts of their subordinates.

This analysis by shipyard size groupings can be summarized by several general conclusions:

- Technology levels tend to vary with shipyard size, with the larger shipyards having the higher technology.
- The medium sized shipyards appear to need more improvement than the larger and smaller shipyards if their technology is to become equal to or surpass that of their foreign counterparts.
- U. S. shipyards lag substantially behind the foreign shipyards in three of the four “hands on” categories involving substantial numbers of the work force. Relative strength in the design, planning and control areas should facilitate improvement in the “hands on” categories without substantial capital investment.

(4) Level 4 Technology Exists in the U.S. for Only 31 of the 70 Elements Surveyed

On Element G4, Steelwork Coding Systems, 12 of the 13 U.S. shipyards surveyed practice Level 4 technology. However, there are a number of elements where none of the U.S. shipyards are as high as Level 4. Table III-1 illustrates this situation by category.

AVAILABILITY OF HIGH TECHNOLOGY

	CATEGORY	TOTAL ELEMENTS	NO.OF ELEMENTS LEVEL 4 FOREIGN	U.S
A.	STEELWORK Production	11	11	1
B.	OUTFIT PRODUCTION & STORES	10	7	5
C.	OTHER PRE-ERECTION ACTIVITIES	5	5	1
D.	SHIP CONST.& INSTALLATION	13 (39)	10 (33)	4(11)
E.	LAYOUTS MATERIALS HANDLING	2	2	1
F.	ENVIRONMENTS AMENITIES	6	6	1
G.	DESIGN. DRAWING, PROD.ENGR. & LOFTING	9	9	8
H.	ORGANIZATIONS OPERATING SYS.	14	14	10
		70	64	31

TABLE III-1

Steel work Production, Category A, is comprised of 1 elements. Level 4 technology has been achieved on al1 the 11 elements by at least one of the 16 foreign shipyards, al though no single foreign shipyard is at Level 4 on all 11 elements. The 13 U.S. shipyards, on the other hand, have reached Level 4

on only one of the 11 elements. Thus, if a U.S. shipyard manager desired to personally observe Level 4 technology in these areas, he would have to visit the appropriate foreign shipyards for ten of the 11 elements.

Outfit Production and *Stores,* Category B, has ten elements. For three of the ten elements there is no Level 4 in the foreign shipyards, covered by the survey, nor does it exist for five of the ten elements in the U.S. shipyards. When individual elements are examined, it is found that Level 4 has not been achieved for two Of the elements in any of the shipyards surveyed, U.S. or foreign.

The first four Categories, A through D, cover the shop and waterfront work, the physical work of shipbuilding. There are 39 elements in these categories. The foreign shipyards have achieved Level 4 on 33 of them, the U.S. shipyards on 11. As previously noted, however, Other Pre-Erection Activities, Category C, provides the most readily discernible indication of the adoption of the technologies which have reduced construction time and man hours abroad. In this category, the U.S. shipyards surveyed had reached Level 4 on only one of the five elements.

The last four categories starting with Layout and Materials Handling, Category E, and ending with Organization and Operating Systems, Category H, cover the planning, control and support of the productive work. Layout of a shipyard is

almost inherent. In some shipyards, however, layout can be improved with additional investment if site restrictions permit. A new, "greenfield" shipyard usually achieves Level 4 in Element El. However, a new shipyard where there is a dependency on old shops in the adjacent older facility will not rate a Level 4 in this element. Utilization of modern material handling devices including conveyors and purpose designed positioning devices is required to achieve a Level 4 assignment for Element E2. Actually, some of the U.S. shipyards that have constructed substantially new shipbuilding facilities in recent years were marked just under Level 4 for Category E.

In Environment and Amenities, Category F, the U.S. shipyards fall far behind. This suggests that the importance of the six elements making up this category should be reviewed for their impact on productivity. It is possible that traditional U.S. practices in this area are not economical in the long run, particularly when employee turnover and training costs are considered.

In the last two Categories (G, H), the U.S. shipyards' technology levels tend to equal those of the foreign shipyards. U.S. shipyards apparently do not market as many new designs as their foreign counterparts, but this is probably due to market factors rather than new design capability. Drawings delivered tO the Shop floor as a part of work packages appear to meet

high technology standards which, in this case, indicates that they are straight forward workpiece drawings suiting the requirements of a particular group of workmen. However, the surveyors did note that intermediate shop and production planning staffs produced many of the workpiece drawings rather than having them produced by the drawing room staff.

Several of the U.S. shipyards have operated, or are operating, pay incentive plans in selected areas. These shipyards, particularly, appear to have a good feel for performance levels and for the status of work. Most of the U.S. shipyards have detailed scheduling systems which establish start dates and durations for the many operations necessary to build a ship. In some cases, there is an indication that these same schedules are not used as the paramount tool in the management of work by shop floor and shipboard first level management. Therefore, while progress is reported against schedule, some work is not supervised by schedule.

One of the criteria with respect to Level 4 assignment in the scheduling elements concerns the loading of manpower and facility resources by workstation. Little evidence was found of the loading of facilities in U.S. shipyards, although there were a few cases where work was diverted to an alternate capability because of facility overload. The fact is that most of the facilities were not fully loaded and did not require

special scheduling and reporting attention. In this situation, Level 4 technology might not be a profitable goal to achieve.

In the aggregate, one or another of the 13 U. S. shipyards surveyed is practicing Level 4 technology in 31 of the 70 elements observed. The U. S. shipyard manager would have to go abroad to sight more than half of the elements, if Level 4 were his goal.

At this time, it is appropriate to note that very few, if any, of the shipyards surveyed, U. S. or foreign, would have been at Level 4 in any of the elements 20 years ago. For many of the elements, Level 4 is a product of the 1970s. Higher technology than Level 4 is difficult to visualize, but higher levels, say Level 5, must exist somewhere in industry. The shipbuilding industry should search out this higher technology.

2. SIXTEEN MOST CRITICAL AREAS ARE IDENTIFIED

In the previous section of this chapter, it was noted that foreign shipyard technology exceeded that of the U. S. shipyards in 51 of the 70 elements surveyed. In this section, 16 of the 51 elements are selected for further consideration.

Appendix G, COMPARISON OF AVERAGE TECHNOLOGY LEVELS BY ELEMENT, contains charts showing, for each element within each category, the average technology level for the 13 U. S. shipyards and the 16 foreign shipyards included in the survey. These charts provide a visual

image of which sector, foreign or U.S., is in the lead on each of the 70 elements, and by how much.

Appendix H, COMPARISON OF ACTUAL TECHNOLOGY LEVELS BY ELEMENT, presents detailed data on the levels achieved by the U.S. and, separately, the foreign shipyards on each of the 70 elements. In the case of these charts, the number of shipyards at each of the four levels is shown as a percentage of the total number of U.S. and foreign shipyards surveyed, respectively. Thus, the distribution of level assignments is readily discernible. It is easy to note whether the preponderance of U.S. shipyards are at Level 1, 2, 3 or 4 for any given element, and similarly for the foreign shipyards.

Together, the information in Appendices G and H provides an overview of the technological leadership, element by element, and of the magnitude of the differences. Obviously, all the elements are not of equal importance and in some cases the differences are minimal. In order to direct attention to the more important elements, a dual selecting out process was employed. First, if the difference between U.S. and foreign shipyard average levels was less than one-half of one level, the element was excluded from the analysis. Second, those elements which passed the first test were reviewed to determine whether they were manpower intensive or manpower sensitive. Manpower intensive elements are those that directly utilize substantial numbers of workers. Manpower sensitive elements

are those concerning processes which may definitely affect the amount of shop and waterfront manpower required. Ship design is an example. It is recognized that these two tests have their limitations, but the process serves to indicate the importance of assigning some sort of priority to each of the elements, particularly when they are being analyzed by individual shipyards.

Overall, 16 of the elements on which foreign shipyards were in the lead passed the two *tests* just outlined. They are listed on Table III-2.

SIXTEEN MOST CRITICAL AREAS

	ELEMENTS	LEVEL DIFFERENCE FOREIGN HIGHER THAN U.S.
C1	MODULE BUILDING	11
C2	OUTFIT PARTS MARSHALLING	.6
C3	PRE-ERECTION OUTFITTING	.5
D2	ERFCTION & FAIRING	.8
D4	ON BOARD SERVICES	6
D8	HULL ENGINEERING	6
G1	SHIP DESIGN	7
G6	PRODUCTION ENGINEERING	7
H1	ORGANIZATION OF WORK	10
A6	SUB ASSEMBLY	9
A8	CURVED UNIT ASSEMBLY	6
A9	3D UNIT ASSEMBLY	8
D3	WELDING	6
F1	GENERAL ENVIRONMENTAL PROTECTION	.7
C4	BLOCK ASSEMBLY	.9
D1	SHIP CONSTRUCTION	8

TABLE III-2

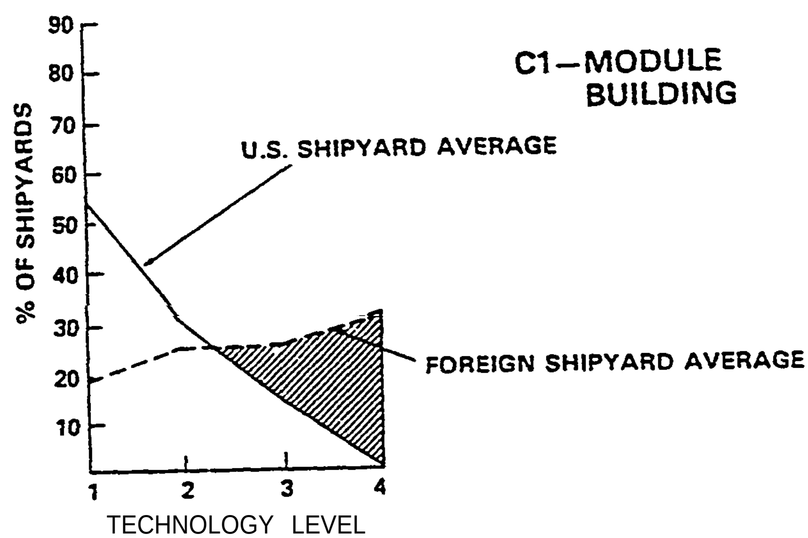
It will be noted that the 16 elements are further divided into groups of nine, five and two elements, respectively. These groupings were based on a subjective judgment of the magnitude of the investment

that would be required to raise the technology levels substantially. A more refined estimate could have been made on a shipyard by shipyard basis, but this would not serve the inmediate purpose which is simply to emphasize that not all technology level improvements would require substantial expenditures.

(1) There Are Nine Critical Areas Wherein the Technology Level of U.S. Shipyards Could be Raised with Minor Capital Investment

Figure III-4 is a chart, similar to those in Appendix H, showing the percent of U.S. and foreign shipyards assigned to each of the four levels for Element Cl, Module Building.

Figure III-4



The chart shows that 54% of the U.S. shipyards were assigned Level 1 while none were assigned Level 4 on Element Cl. 31% of the foreign shipyards were assigned Level 4. The shaded area gives some indication of the magnitude of the technology

difference. There are several definitions for modules which vary from the definition used in this report. In this context, a module is an assembly of equipment on a foundation together with piping, valves, cabling and, in some cases, part of the ship's structure.

The nature of the criteria used to distinguish between each of the four technology levels has been discussed earlier in this report and eight examples are included in Appendix B. In the case of the Module Building element, the differences between Level 1 and Level 4 are shown in condensed form as follows:

- Level 1

  No Module Building

- Level 4

  Large scale module.assembly

  Integrated with steelwork

  Purpose designed work area

  Extensive pre-planning

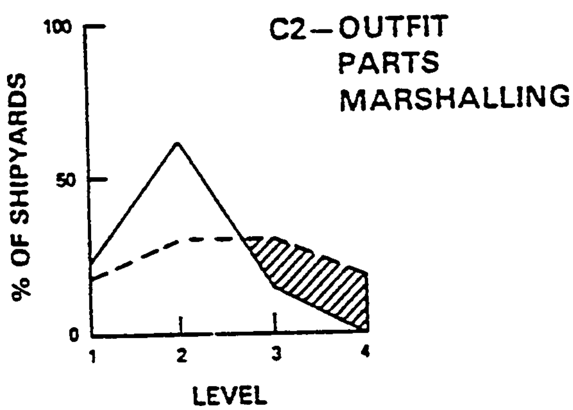
  Testing prior to installation

Upon examination of the criteria, it will be noted that many of the differences, Level 1 to Level 4, could be effected without significant investment. Rather, the major changes would be in the planning and engineering areas and could be effected through management initiative.

A similar technique will be used to present the remaining 15 critical elements. That is, the element will be named and a brief comment as to level differences will be provided. Then, the chart and a condensation of the most pertinent technology level criteria will be shown. In each case, U.S. shipyard data will be shown by solid lines, foreign by dashed lines.

- o Element C2, Outfit Parts Marshalling (Figure III-5), covers the assembly of parts prior to production. The U.S. shipyards peak at Level 2 while there are a number of foreign shipyards at Levels 3 and 4.

Figure III-5



Level 2

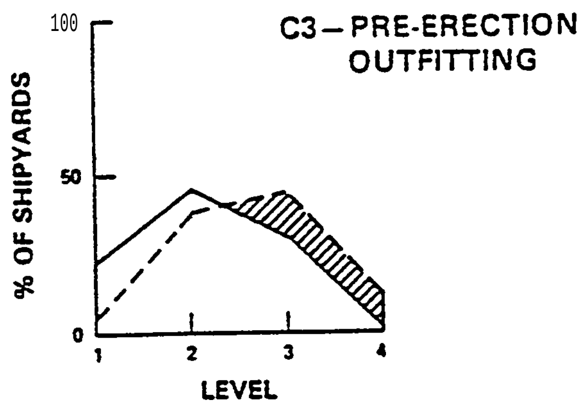
Some parts kitting prior to production

Level 3

Majority of parts kitted in a designated area prior to dispatch to production areas

0 Element C3, Pre-Erection Outfitting (Figure III-6), covers the outfitting of units and blocks prior to erection on the berth. The U.S. shipyards peak at Level 2 while the foreign shipyards peak at Level 3.

Figure III-6



Level 2

Partial preoutfitting of units by installation of pipe supports, cable hangers and some painting

Level 3

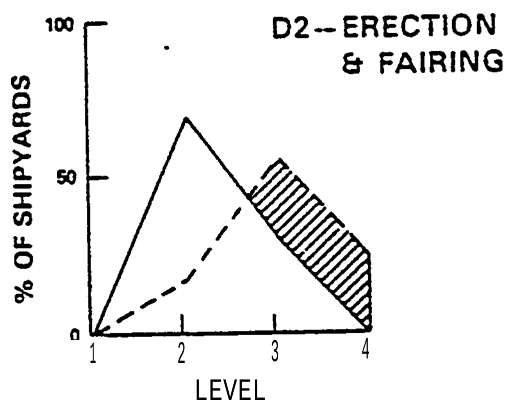
Substantial preoutfitting of units and blocks. Includes pump, engine and control rooms.

Level 4

Complete preoutfitting with systems finished and tested

0 Element D2, Erection and Fairing (Figure III-7), covers erection of the ship-on the berth. U.S. and foreign shipyards peak at Levels 2 and 3, respectively.

Figure III-7



Level 2

Long hanging time -- 1 hour plus

Surplus stock on plate edges

Fairing by welded fairing aids, hammers, etc.

Level 3

Short hanging time -- 1/2 hour or less

Limited surplus stock, good dimensional

Stud fairing, hydraulic fairing

Level 4

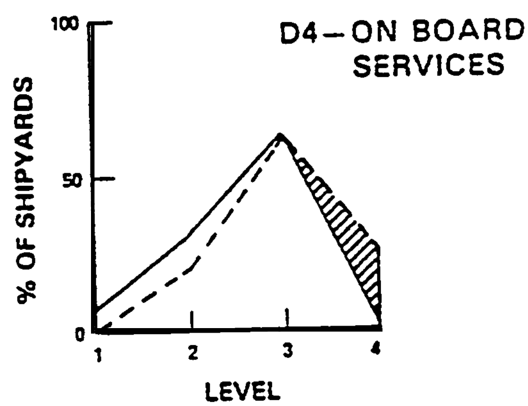
Large self-supporting blocks

No surplus left on edges

Non-welded fairing aids; purpose designed

0 Element 04, On Board Services (Figure III-8), covers the supply of gas, water, electricity and air to the workforce aboard ship. Both foreign and U.S. shipyards peak at Level 3, but 25% of the foreign shipyards are at Level 4.

Figure III-8



Level 3

Extensive services on board

Main supplies in selected routes

Welding equipment grouped for easy removal

Routing designed to suit ship and work plan

Level 4

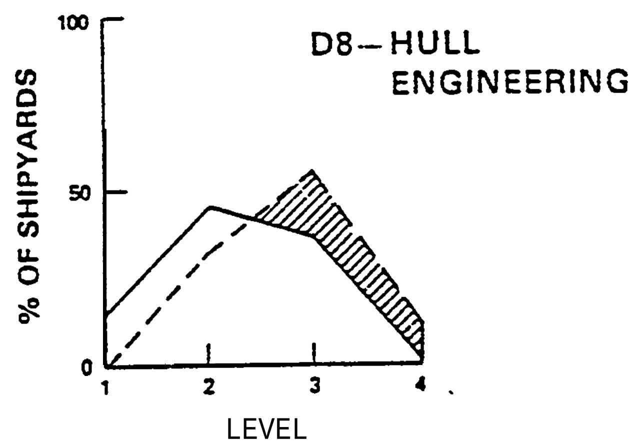
All routing pre-planned

Services in modular form to facilitate expansion -- contraction

All cables and hoses clear of deck

0 Element D-8, Hull Engineering (Figure III-9), covers installation of deck machinery, hatch covers, steering engines, ladders, etc. Again, the U.S. shipyards peak at Level 2, the foreign shipyards at Level 3.

Figure III-9



Level 2

Some alignment of seats

Some pre-erection installation of deck units

Majority of installations after launch

Level 3

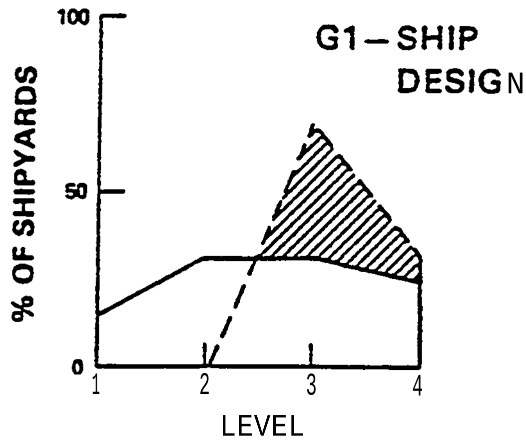
Hull machinery fitted and chocked prior to launch

Significant outfitting of units prior to erection

Installation work advanced to an early stage of construction

o Element Gl, Ship Design (Figure III-10), precedes and is differentiated from detailed drafting. U.S. shipyards show up at all levels while all the foreign shipyards are at Level 3 or 4.

Figure III-10



Level 2

Small design department

Principally modifies purchased or clients' designs to suit facilities and methods

Level 3

Markets its own designs

Computer programs used

Limited data bank available

No original research

Level 4

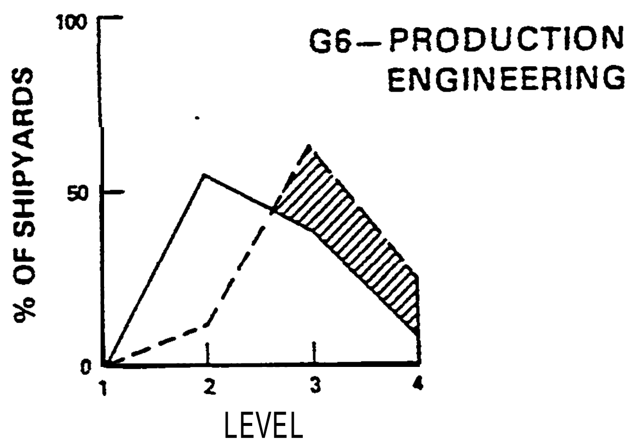
Extensive design function, many specialists

Highly computerized, interactive graphics

Many designs available, original research

- o Element G6, Production Engineering (Figure III-11), stresses the planning of construction of specific ships. How best to assemble all the pieces? U.S. shipyards do carry out a number of production engineering functions, but many do not emphasize this particular facet. The U.S. shipyards are predominantly at Level 2 while foreign shipyards peak at Level 3.

Figure III-11



Level 2

An individual or small department

Limited standards

Little involvement of the production engineering department in detailed design beyond initial block breakdown

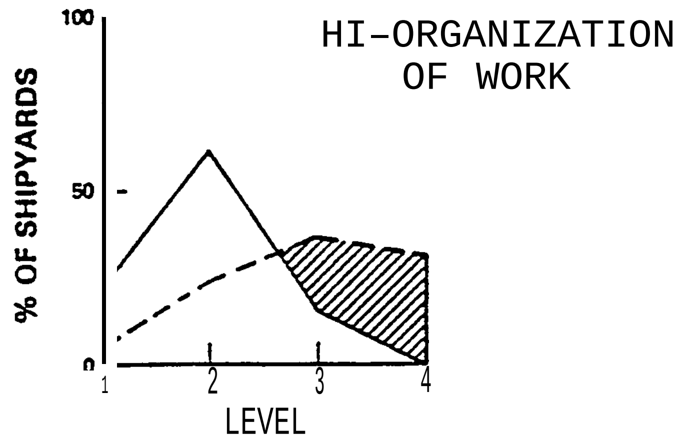
Level 3

Production engineering department linking technical and production functions

Well established standards and methods

0 Element HI, Organization of Work (Figure III-12), applies to flexibility in supervising and assigning work to craftsmen. U.S. shipyards peak at Level 2, the foreign shipyards at Levels 3 and 4.

Figure III-12



Level 2

Trade structure with shop and ship split

Some sharing of "helping" tasks

Level 3

Area supervision

High level of flexibility and interchangeability

Level 4

Workstation organization with maximum flexibility

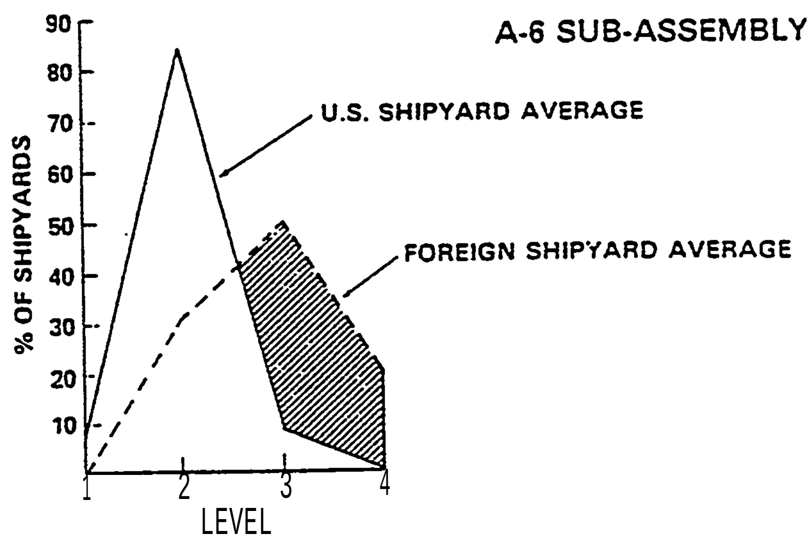
As previously indicated, it appears that higher technology levels could be achieved in several of the nine elements just highlighted with only minor investment. Of course, different conditions exist in the different shipyards which would affect the investment required. In many cases, however, a management decision to achieve the higher technology, followed by advancing the schedule dates on which design, procurement and other actions supporting production are to be completed, would be all that is necessary. It is recogonzed that this is not easy, particularly when series production programs are the exception. Some means of reducing long lead times would also help to make it possible to advance planning, design and procurement actions.

(2) There are Five Critical Areas Where Moderate Capital Investment Would Raise the Level of Technology

The five elements discussed below are more equipment and facilities oriented than the nine elements discussed in the previous section. This even applies to the General Environmental Protection element where shelters and other means of protecting the work force from the weather are a factor. For the other elements, the required equipment, fixtures and changes in layout can also be quite expensive. Thus, these five elements have been roughly classified as requiring moderate capital investment.

o Element A6, Sub-Assembly (Figure .III-13) covers parts of main units, e.g., installing brackets and stiffeners on floors, etc. U.S. shipyards peak at Level 2, foreign shipyards at Level 3.

Figure III-13



Level 2

Work at defined workstations

Some fairing aids

Logical material flow

Mostly manual metal arc welding

Level 3

Fixed services and work positioners

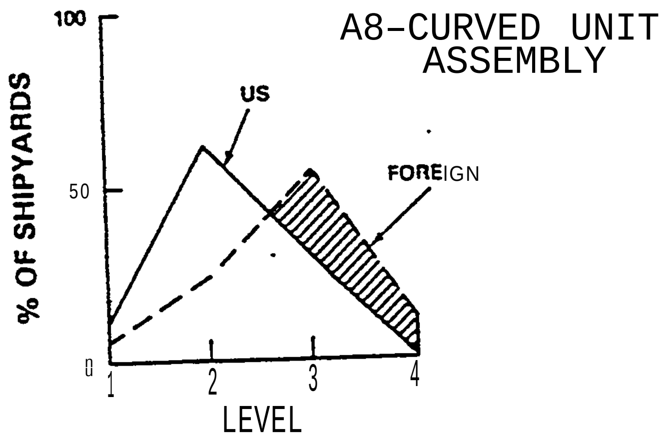
Mechanized sub-assembly line

Extensive use of jigs

Automatic and semi-automatic welding

0 Element A-8, Curved Unit Assembly (Figure III-14), covers single and double curved shell units, bilge units, etc. U.S. shipyards peak at Level 2 while the foreign shipyards peak at Level 3 with some at Level 4.

Figure III-14



Level 2

Defined workstation, simple jigs, supports

Fairing by welded attachments

Welding, manual metal arc except automatic seam welding

Level 3

Fixed workstations, telescopic jigs, molds

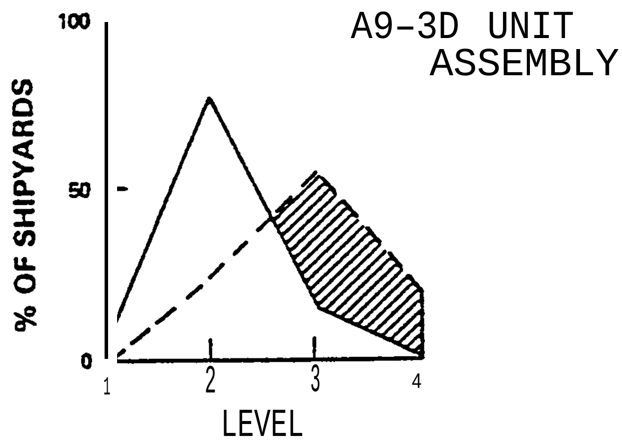
Fairing by purpose designed equipment, e.g., magnetic, hydraulic

Orienting panels, units to facilitate work

One side welding, high deposit electrodes, semi-automatic equipment

o Element A9, 3-D Unit Assembly (Figure III-15), covers totally enclosed units. U.S. shipyards peak at Level 2 while foreign shipyards are at Levels 3 and 4.

Figure III-15



Level 2

Substantial amount of assembly carried out in defined, covered workstations

Fairing by welded attachments

Welding mainly manual metal arc

Level 3

Most assembly done under cover

Pre-assembled units used extensively

High deposit electrodes and/or semi-automatic equipment

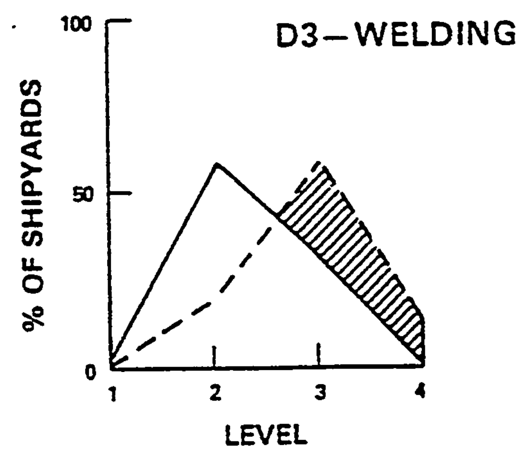
Level 4

Covered, purpose designed work stations

Extensive use of automatic down hand and vertical welding machines, one side welding

0 Element 03, Melding (Figure III-16), covers welding during the erection and outfitting of the ship on the building berth and after launch. U.S. shipyards peak at Level 2, foreign at Level 3.

Figure III-16



Level 2

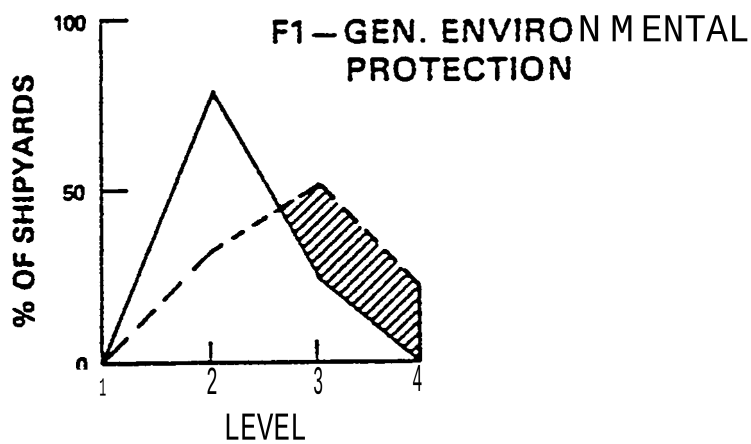
- Mainly manual metal arc, some automatic tractors and semi-automatic sets
- Some effort to improve welder mobility .
- Careful selection of electrodes by application

Level 3

- Some manual metal arc with remote control
- Good electrical services, good mobility
- More use of automatic welding tractors
- Carefully prepared joints, one side welding
- Semi-automatic and stud welding sets used

o General Environmental Protection (Figure III-17), Element Fl, emphasizes the working conditions offered by the buildings, protection of the workforce from the weather, and housekeeping. About 75% of U.S. shipyards are Level 2, 70% of foreign at Levels 3 and 4.

Figure III-17



Level 2

Mainly old buildings with below average working conditions

Limited weather protection for workforce

Poor housekeeping in some areas

Level 3

Above average working conditions

Majority of outside workforce given some protection from the weather

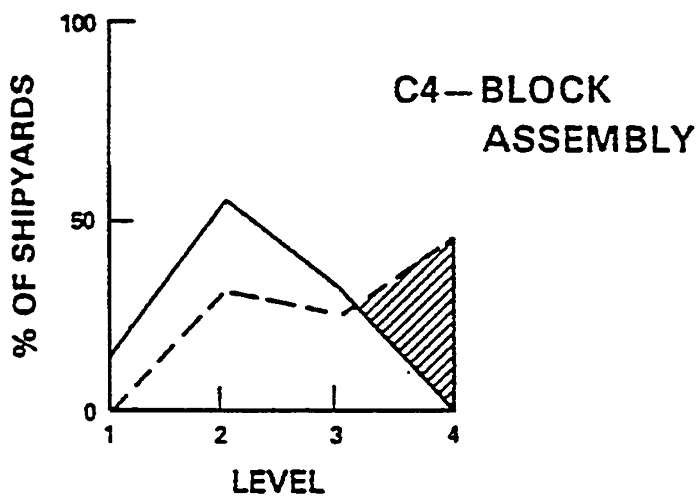
Generally good housekeeping

(3) There Are Two Critical Areas Requiring Major Capital Investment to Raise the Level of Technology

A high technology level assignment for the last two of the 16 critical elements requires a building in which to assemble large blocks with heavy lift capability and special facilities,usually a basin, to permit tandem or similar construction. All these requisites are very costly.

- o Element C4, Block Assembly (Figure III-18), U. S. shipyards are predominantly at Level 2 while nearly 50% of the foreign shipyards are at Level 4.

Figure III-18



- Level 2

  Limited block assembly in outside area

  Conventional fairing

  Primarily manual metal arc welding

Level 3

Block assembly in covered halls

Hydraulic or mechanical fairing

Some semi-automatic, automatic welding

Level 4

Block assembly hall integrated with berth

Block breakdown to facilitate preoutfitting

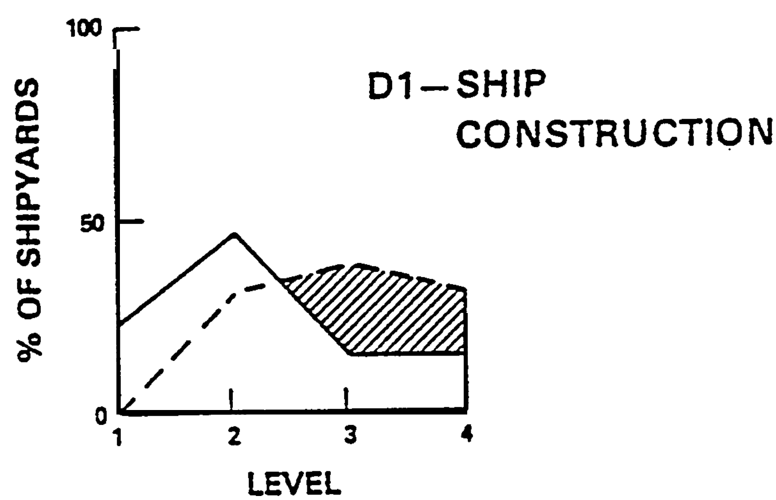
Accurate unit and block dimensions

Purpose designed services, support and fairing systems

Extensive automatic, semi-automatic welding

0 The final critical area is Ship Construction (Figure III-19), Element D-1. The U. S. shipyards peak at Level 2 while the foreign shipyards are almost evenly divided at Levels 2, 3 and 4.

Figure III-19



Level 2

Two or three berths in use

Medium capacity cranes

Single stage construction

Two to four ships per berth per year

Level 3

Building dock, berths or transfer system

Large capacity cranes

Semi-tandem, tandem or multi-stage construction

Construction area partially covered

Level 4

Similar to Level 3, but

- No inclined ways
- Substantial or complete environmental protection
- High output .

There are many other elements on which foreign shipyard technology is significantly higher than in the U.S. shipyards, and five will be discussed in the next section. However, as previously stated, the 16 just discussed generally appear to be the most important in terms of reducing construction time and man days. Overall, the foreign shipyards were assigned equal or higher technology levels on 51 of the 70 elements surveyed.

3. TECHNOLOGY LEVELS ARE VERY LOW IN FIVE ADDITIONAL AREAS

Another viewpoint is provided by simply identifying elements where U.S. technology is inherently low in an absolute as opposed to a comparative sense. There are five elements, not discussed in the previous section, for which U.S. shipyard technology level averages are 2.0 or below. These elements are listed in Table III-3 below.

TABLE III-3

.ADDITIONAL.ELEMENTS FOR WHICH U.S. SHIPYARD TECHNOLOGY LEVELS ARE LOW

Element	Title	Avg. Level
A4	Stiffener Cutting	
A11	Outfit Steelwork	1.8
B1	Pipework	2.0
B2	Engineering (Machining)	1.9
F6	Other Amenities	1.2

The diagrams showing U.S. (and foreign) shipyard performance on each of these elements are contained in Appendix H. With few exceptions, the technology levels noted for these elements in the U.S. shipyards surveyed characterize shipyards of the 1950-1960 era. In fact, 61 of the 65 level assignments made for these five elements in the 13 U.S. shipyards surveyed were assigned Level 1 or Level 2. This suggests the possibility of making substantial improvements in these areas. It is noted that four of these elements involve physical activities that consume significant amounts of manpower.

4. WHERE U.S. SHIPYARDS LOOK GOOD

U.S. shipyards have expended substantial sums of money in modernizing facilities and equipment and they have developed extensive management systems for scheduling, controlling and supporting work. At least to some extent, these efforts are reflected in the 16 elements in which average U.S. shipyard technology is higher. In nine of these cases, U.S. technology exceeds that of the foreign shipyards by a level difference of .3 or more as indicated in the following table:

TABLE III-4

WHERE U.S. SHIPYARDS LOOK GOOD

	Elements	Level Difference U.S. Higher Than Foreign
A3	Plate Cutting	.3
B11	Auxiliary Storage	.6
D13	Testing and Commissioning	.7
G4	Steelwork Coding	.4
G5	Parts Listing	.5
H3	Steelwork Prod. Scheduling	.5
H8	Outfit Prod. Scheduling	.3
H9	Outfit Installation Control	.4
H10	Ship Construction Control	.6

(1) U.S. Shipyard Technology Is Significantly Higher Than Foreign In Three "Hands On" Elements

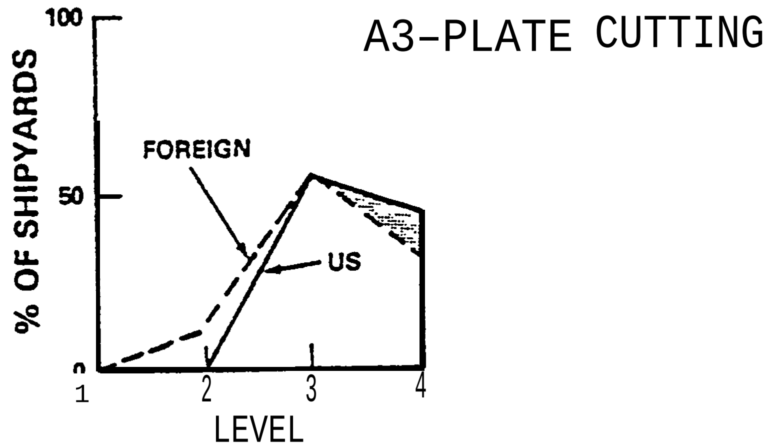
Of the 9 elements listed in Table III-4, three involve physical "hands on" activities.

- o Element A3, Plate Cutting (Figure III-20)*

  U.S. shipyards were assigned Level 3 and Level 4

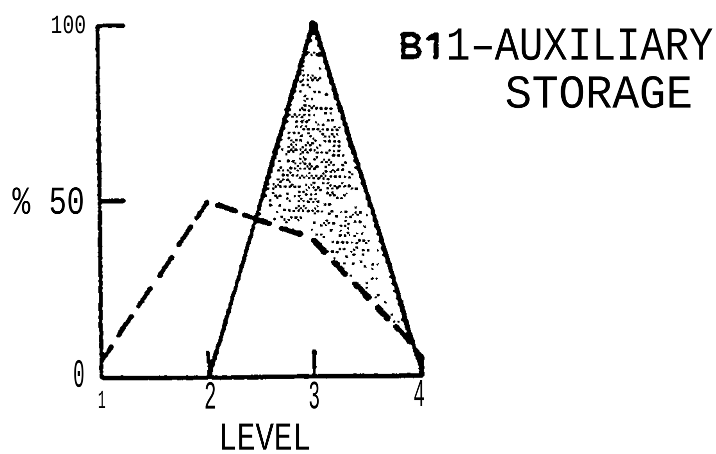
almost equally. All the U.S. shipyards' plate cutting equipment was tape driven and many had 3-axis burning capability.

Figure III-20



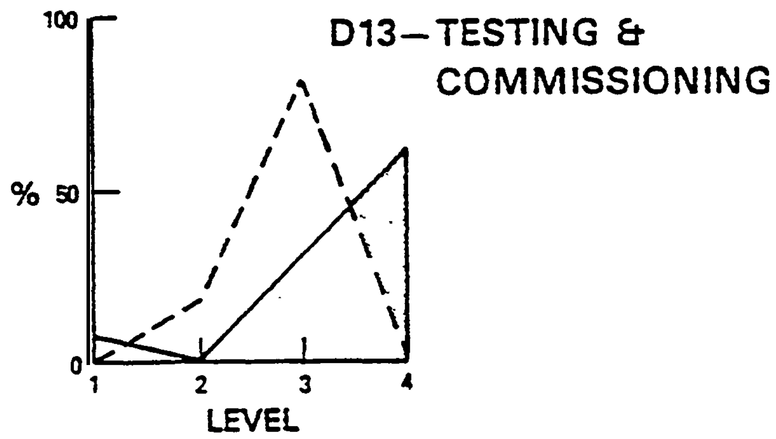
0 All U.S. shipyards were assigned technology Level.3 on Element Bll, Auxiliary Storage (Figure III-21). The criteria include the use of heavy duty pallets when appropriate, defined storage locations and good handling arrangements.

Figure III-21



o More that 60% of the U.S. shipyards were assigned Level 4 on Element D13, Testing and Commissioning (Figure III-22) which requires a highly organized operation and extensive records of all types of tests and trials. The high levels assigned probably can be related to the complexity of ships, particularly naval ships, built in many U.S. shipyards and, also, the relative stringency of our regulatory bodies.

Figure III-22



(2) <u>The U.S. Shipyards Excel in Several of the Planning and Control Elements</u>

o Two of the elements, Steelwork Coding System, Element G4, (Figure III-23) and Parts Listing Procedures, Element G5, (Figure III-24), are well in hand with 90% and 70% of the U.S. shipyards, respectively, assigned technology Level 4.

This level requires standard, consistent codes and in the latter case, a computer based system.

Figure III-23

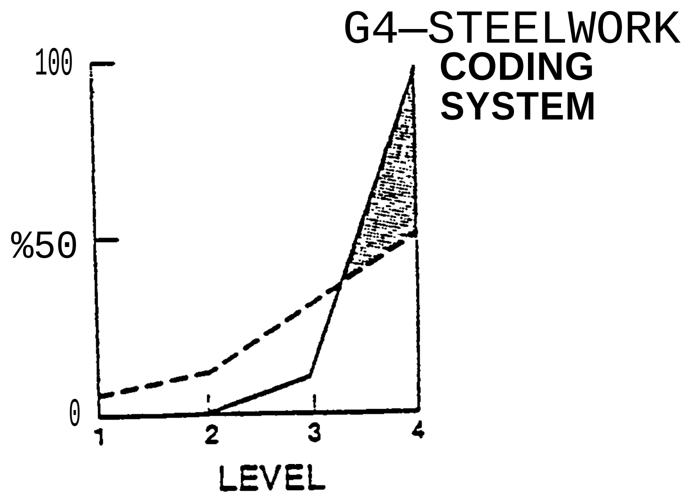
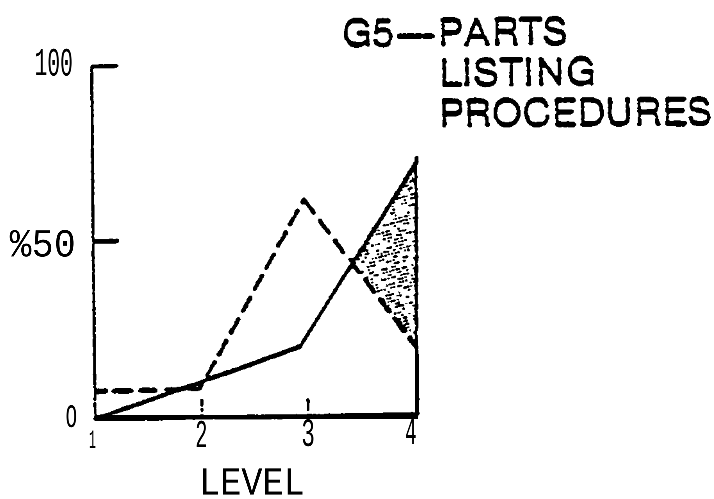


Figure III-24



o The four elements pictured on Figures III-25, 26 27 and 28 involve scheduling and control of work. In each case, as in the two cases above, the U.S. shipyards are predominantly at Level 4.

Figure III-25

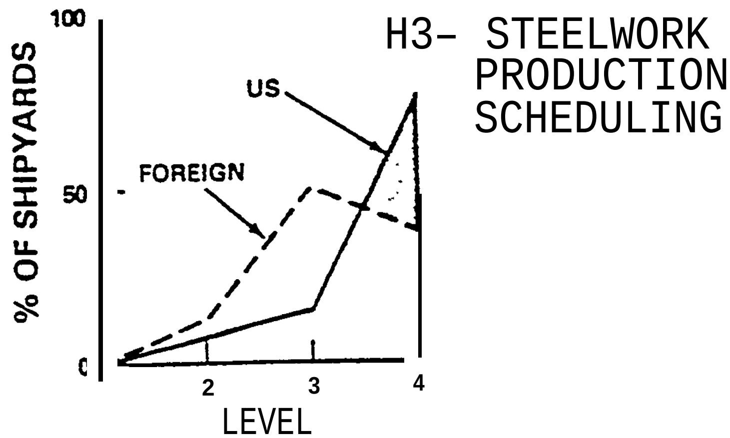


Figure III-26

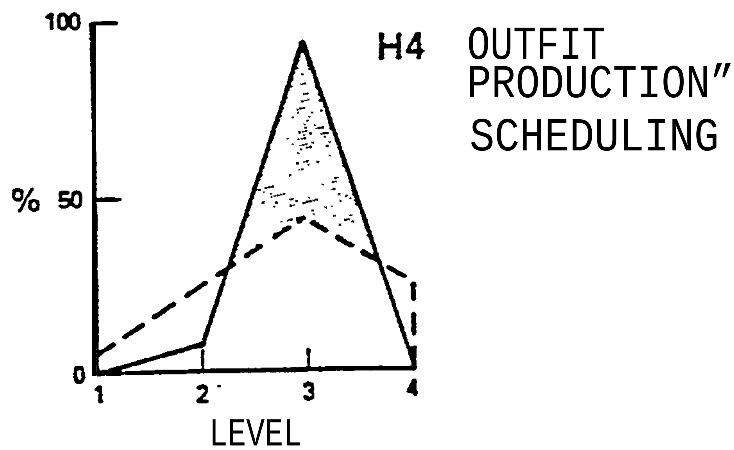


Figure III-27

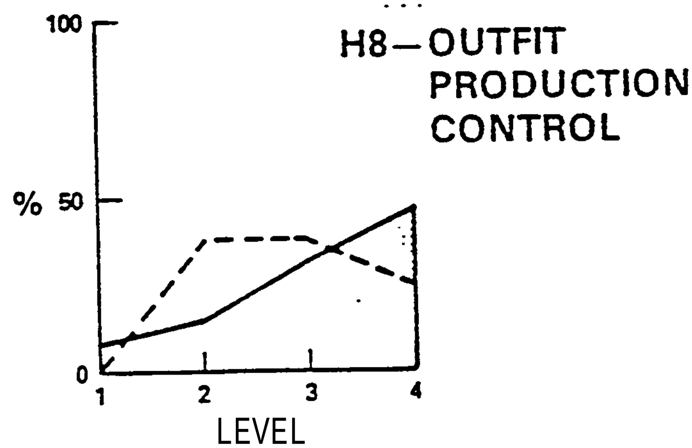
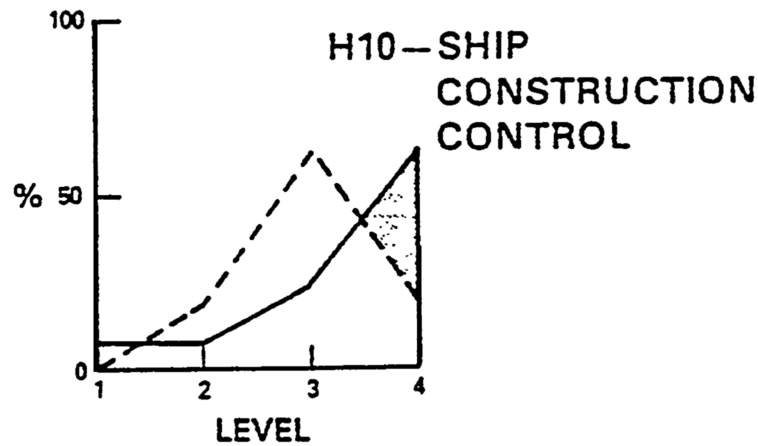


Figure III-28



On the average, the U.S. shipyards were assigned high technology levels on those elements involving the coordination and control of shop and ship work. The very nature of the task of meshing all of the actions, physical and otherwise, essential to building a complex ship, coupled with Department of Defense work management requirements, certainly has contributed to this good showing.

5. ANALYSIS OF LEVEL DIFFERENCES

The data presented in condensed form in the preceding sections of this chapter show that the average technology level of the U.S. shipyards surveyed is lower than in the foreign shipyards. However, there are many factors which must be taken into consideration by a shipyard in formulating its plans for improvement.

(1) Why There Are Differences In The U.S. And Foreign Shipyard Technology Levels

The 70 elements considered in this survey can be grouped into broad areas such as:

- Assembly
- Design and engineering
- Planning and control
- Working conditions
- Manufacturing.

Probably the single most important requisite to making major investments in the assembly areas, including block assembly and ship construction, is to have orders supporting economies of scale. Level 4 technology in these areas calls for purpose designed jigs, fixtures and equipment, heavy lift capability, etc. which are not readily adaptable to small runs of different type ships, at least not efficiently. Thus, if the market does not provide a basis for long range programming, individual shipyards must determine whether the highest level of technology, with its inflexibilities in some cases, is economical for them.

The same factors tend to apply in the design and engineering area. Developing and marketing a number of designs will not be cost effective if the market is severely limited.

In the engineering area, the detailed design of structure and systems traditionally has followed a different pattern than the actual erection of units, blocks and the complete ship. For example, systems frequently are designed in their entirety . and drawings are provided to the shops in whole or in large segments. It is an additional step to provide tailored drawings free of extraneous detail to each workstation. However, with a sufficient run of ships of a given design, the economies realized at the workstation level more than offset the additional cost of engineering.

One of the factors contributing to Level 4 assignments in the planning and control area involves the workloading of workstations during the scheduling process. Most of the U.S. shipyards have a thorough knowledge of workload in the steelwork areas, e.g., plate cutting and panel fabrication. However, in many of the other production areas, workloading was not a significant factor since excess capacity existed. Thus, schedulers did not have to concern themselves with capacity limitations, and this resulted in lower technology level assignments.

There were distinct differences in technology level assignments for the working conditions (Environment and Amenities, Category F) area. While these differences, for example in food service facilities, can be eliminated by local shipyard management

action, little concerted effort to do so was observed during the surveys. It may not be a cost effective action. However, the industry in general has problems with employee turnover, and working conditions are usually attributed to be one of the causes. The differences between U.S. and foreign shipyard level assignments in this area may not be the result of differing social customs but, rather, may reflect the findings of cost analyses.

The manufacturing area poses still other kinds of questions. There is the perennial "make or buy" question and to this is added the question, "Should the shipyard buy pieces of equipment or complete modules?" More and more, modules seem to be assembled in-house. Additionally, there is the question of the cost of equipment needed for highly efficient manufacturing operations; for example, NC tools in the sheetmetal shop to manufacture lockers. There appears to be many areas where a central capability serving several shipyards or industries would be economical.

To summarize, there are a number of factors that have contributed to the differences in technology levels found in this survey. It is probable that the lack of production runs of given designs is the major factor. Moreover, without large runs, Level 4 may not be an economical goal for a number of the elements. Overall, however, it does appear that there are a

number of opportunities for increasing technology levels, many without a substantial investment.

(2) The Growth in Ship Size has Affected Technology Levels

In a previous section of this chapter, it was shown that the technology levels of large shipyards are higher than the levels of medium and, particularly, smaller shipyards. This finding applies to both U.S. and foreign shipyards. There is reason to believe this difference can be related to the demand for larger and larger ships. Very simply, VLCCS and ULCCS could not be constructed efficiently, if at all, in shipyards of the 1950s and early 1960s. Therefore, when the market developed, new shipyards had to be built or old shipyards had to be drastically altered. The U.S. shipyards were slow to enter this market since the ships could not trade in U.S. ports because of their size. During the process of building new shipyards, or drastically altering older shipyards, the entire production process was usually rationalized. The result was the high technology levels attained by many foreign shipyards.

The U.S. shipyards that have reacted to this market have taken advantage of the situation to move up on the technology scale, at least in some areas. This has involved major expense which can be recouped given a reasonable order book.

A few of the smaller shipyards, U.S and foreign, have moved towards higher technology purely for cost effectiveness

reasons. Covered building berths and new assembly halls have been erected in some instances. The justification has been a reasonably predictable market for ships of the size and type usually constructed in the smaller shipyards. However, it can be argued that these latter changes were inspired more by the experiences and successes of the big ship shipyards than the pressures on the market created by the orders for smaller ships, particularly in the U.S.

(3) Opportunities

In the preceding sections, a number of possible actions have been suggested which appear to offer opportunities for improved performance in terms of reducing man hours and time to build. These are set forth in the Summary Chapter which follows.

IV. BASIC DATA

IV BASIC DATA

The following tables display all the basic shipbuilding technology level determinations made during the survey of the 13 major U. S. shipyards and 16 foreign shipyards:

Table IV-I: LEVELS OF SHIPBUILDING TECHNOLOGY IN U. S. SHIPYARDS

Shows the levels of shipbuilding technology used by the 13 major U. S. shipyards plus the General Dynamics sphere facility in Charleston, South Carolina. The alphabetical designation of shipyards was done randomly to protect the confidentiality of shipyard data.

Table IV-2: LEVELS OF TECHNOLOGY IN COMPARABLE FOREIGN SHIPYARDS

Shows the levels of shipbuilding technology used by the 16 comparable foreign shipyards. The alphabetical designation of shipyards is required to protect the confidentiality of shipyard data.

Table IV-3: LEVELS OF TECHNOLOGY IN THIRTEEN U. S. SHIPYARDS BY LEVEL

Shows the average level of technology used in the U. S. shipyards for each element and major category, plus the number of shipyards at each of the technology levels by element.

Table IV-4: LEVELS OF TECHNOLOGY IN SIXTEEN FOREIGN SHIPYARDS BY LEVEL

Shows the average level of technology used in the 16 comparable foreign shipyards for each element and major category, plus the number of shipyards at each of the technology levels by element.

Table IV-5: LEVELS OF TECHNOLOGY IN U. S. SHIPYARDS BY LEVEL IN PERCENT

Shows the level of technology in terms of the percent of the 13 U. S. shipyards at each level for each element.

Table IV-6: LEVELS OF TECHNOLOGY IN FOREIGN SHIPYARDS BY LEVEL IN PERCENT

Shows the level of technology in terms of the percent of the 16 foreign shipyards at each level for each element.

..%

Table IV-1

LEVELS OF SHIPBUILDING TECHNOLOGY IN U.S. SHIPYARDS

	U.S. Shipyards						
	A	B	C	D	E	F	G
STEELWORK PRODUCTION							
A1 Plate Stockyard & Treatment	2	3	3	3	3	3	3
A2 Stiffener Stockyard & Treatment	2	2	2	3	3	2	2
A3 Plate Cutting	4	4	3	3	4	3	4
A4 Stiffener Cutting	1	2	1	2	2	1	1
A5 Plate & Stiffener Forming	3	2	1	2	3	2	2
A6 Sub-Assembly	2	2	2	2	3	1	2
A7 Flat Unit Assembly	3	3	2	3	3	1	3
A8 Curved & Corr. Unit Assembly	2	2	3	3	3	2	2
A9 3D Unit Assembly	2	2	2	2	3	2	3
A10 Superstructure Unit Assembly	2	2	2	3	2	3	2
A11 Outfit Steelwork	1	2	2	2	2	1	2
Average	2.2	2.4	2.1	2.5	2.8	1.9	2.4
OUTFIT PRODUCTION & STORES							
B1 Pipework	2	2	2	2	3	2	2
B2 Engineering	1	1	2	2	3	2	2
B3 Blacksmiths	4	4	4	4	4	4	4
B4 Sheetmetal	1	2	2	3	3	2	2
B5 Woodworking							
B6 Electrical	2	2	2	2	4	3	2
B7 Rigging	2	2	2	3	3	2	3
B8 Plant Maintenance	2	2	2	3	3	2	3
B9 Garage	3	4	3	4	3	3	2
B10 General Storage	2	2	3	3	3	3	2
B11 Auxiliary Storage	3	3	3	3	3	3	3
Average	2.2	2.4	2.5	2.9	3.2	2.6	2.5
OTHER PRE-ERECTION ACTIVITIES							
C1 Module Building	1	1	2	2	2	2	1
C2 Outfit Parts Marshalling	1	2	2	3	2	2	1
C3 Pre-erection Outfitting	2	2	2	3	3	3	1
C4 Block Assembly	1	2	2	3	3	3	2
C5 Unit & Block Storage	1	3	2	4	4	3	3
Average	1.2	2.0	2.0	3.0	2.8	2.6	1.6

Table IV -1 Continued

LEVELS OF SHIPBUILDING TECHNOLOGY IN U.S. SHIPYARDS

	U.S. Shipyards						
STEELWORK PRODUCTION	H	I	J	K	L	M	N
A1 Plate Stockyard & Treatment	2	3	2	3	2	2	3
A2 Stiffener Stockyard & Treatment	2	3	2	3	2	1	4
A3 Plate Cutting	3	4	3	4	3	3	3
A4 Stiffener Cutting	1	2	1	2	2	2	2
A5 Plate & Stiffener Forming	2	3	2	3	2	2	2
A6 Sub-Assembly	2	2	2	2	3	2	2
A7 Flat Unit Assembly	2	3	1	2		2	2
A8 Curved & Corr. Unit Assembly	2	2	1	3	3	2	2
A9 3D Unit Assembly	2	2	1	2		2	2
A10 Superstructure Unit Assembly	2	2	2	2		3	3
A11 Outfit Steelwork	2	2	2	2	3	2	2
Average	2.0	2.5	1.7	2.5	2.5	2.1	2.3
OUTFIT PRODUCTION & STORES							
B1 Pipework	2	2	1	2	3	2	2
B2 Engineering	2	2	1	3	3	2	2
B3 Blacksmiths	4	4	4	4	-	3	4
B4 Sheetmetal	2	3	1	2	-	2	2
B5 Woodworking							
B6 Electrical	2	3	2	2	-	2	2
B7 Rigging	2	4	2	3	-	2	2
B8 Plant Maintenance	2	4	1	3	4	2	2
B9 Garage	2	4	3	4	3	3	2
B10 General Storage	2	3	1	2	2	2	2
B11 Auxiliary Storage	3	3	3	3	3	3	3
Average	2.3	3.2	1.9	2.8	3.0	2.3	2.3
OTHER PRE-ERECTION ACTIVITIES							
C1 Module Building	1	3	1	3		1	1
C2 Outfit Parts Marshaling	2	2	1	2	2	2	3
C3 Pre-Erection Outfitting	2	2	1	2	3	1	3
C4 Block Assembly	3	2	1	2		2	2
C5 Unit & Block Storage	1	3	1	3	2	2	1
Average	1.8	2.2	1.0	2.4	2.3	1.6	2.0

Table IV-1 Continued

LEVELS OF SHIPBUILDING TECHNOLOGY IN U.S. SHIPYARDS

	U.S. Shipyards						
SHIP CONSTRUCTION AND OUTFIT INSTALLATION	A	B	C	D	E	F	G
D1 Ship Construction	2	2	2	4	4	2	3
D2 Erection and Fairing	2	2	2	3	3	2	3
D3 Welding	2	2	3	2	3	2	3
D4 On-Board Services	2	3	3	3	3	3	2
D5 Staging and Access	2	2	2	3	3	2	3
D6 Pipework	2	2	2	2	3	3	3
D7 Engine Room Machinery	2	3	2	3	3	3	2
D8 Hull Engineering	2	2	2	3	3	3	1
D9 Sheetmetal Work	3	3	3	4	4	3	3
D10 Woodwork							
D11 Electrical	3	2	2	3	3	3	1
D12 Painting	4	3	2	3	3	3	3
D13 Testing and Commissioning	4	3	3	4	4	3	4
D14 After Launch	3	3	3	3	3	3	2
Average	2.5	2.5	2.4	3.1	3.2	2.7	2.5
LAYOUT AND MATERIALS HANDLING							
E1 Layout and Material Flow	3	3	2	4	3	3	2
E2 Materials Handling	2	3	2	3	3	3	2
Average	2.5	3.0	2.0	3.5	3.0	3.0	2.0
ENVIRONMENT AND AMENITIES							
F1 General Environmental Protection	2	2	2	2	3	2	2
F2 Lighting and Heating	3	2	3	3	2	2	3
F3 Noise, Ventilation & Fume Extr.	3	2	3	2	3	2	2
F4 Canteen Facilities	2	2	2	3	1	1	2
F5 Washrooms/W.C.'s/Lockers	2	2	2	2	2	2	2
F6 Other Amenities	1	1	1	1	3	1	1
Average	2.2	1.8	2.2	2.2	2.3	1.7	2.0

Table IV-1 Continued

LEVELS OF SHIPBUILDING TECHNOLOGY IN U.S. SHIPYARDS

	U.S. Shipyards						
SHIP CONSTRUCTION AND OUTFIT INSTALLATION	H	I	J	K	L	M	N
D1 Ship Construction	2	2	1	3	4	1	1
D2 Erection and Fairing	3	2	2	2	4	2	2
D3 Welding	2	3	2	2	4	2	2
D4 On-Board Services	2	2	1	3	4	3	3
D5 Staging and Access	2	3	1	2	4	2	1
D6 Pipework	3	3	2	2	4	2	2
D7 Engine Room Machinery	3	3	2	3		1	3
D8 Hull Engineering	2	3	2	2		1	3
D9 Sheetmetal Work	3	4	2	3		3	3
D10 Woodwork							
D11 Electrical	2	3	2	3		2	2
D12 Painting	2	3	2	2		1	2
D13 Testing and Cormnissioning	4	4	3	1	4	4	4
D14 After Launch	2	3	3	3		1	2
Average	2.5	2.9	1.9	2.4	4.0	1.9	2.3.
LAYOUT AND MATERIALS HANDLING							
El Layout and Material Flow	3	2	2	2	4	2	2
E2 Materials Handling	2	3	2	3	2	2	2
Average	2.5	2.5	2.0	2.5	3.0	2.0	2.0
ENVIRONMENT AND AMENITIES							
F1 General Environmental Protection	2	2	2	3	3	2	3
F2 Lighting and Heating	2	2	2	2	3	2	2
F3 Noise, Ventilation & Fume Extr.	2	2	2	3	2	2	2
F4 Canteen Facilities	2	2	1	4	2	2	3
F5 Washrooms/W.C.'s Lockers	2	2	2	3	2	2	3
F6 Other Amenities	1	1	2	1	1	1	1
Average	1.8	1.8	1.8	2.7	2.2	1.8	2.3

Table IV-1 Continued

LEVELS OF SHIPBUILDING TECHNOLOGY IN U.S. SHIPYARDS

DESIGN, DRAFTING, PRODUCTION -ENGINEERING AND LOFTING		U.S. Shipyards A	B	C	D	E	F	G
G1	Ship Design	2	3	3	3	4	2	4
G2	Steelwork Drawing Presentation	3	3	3	2	4	3	2
G3	Outfit Drawing Presentation	2	3	3	3	4	3	3
G4	Steelwork Coding Systems	4	4	4	3	4	4	4
G5	Parts Listing Procedures	2	3	4	4	4	4	3
G6	Production Engineering	2	3	2	3	4	2	3
G7	Design for Production	2	2	2	4	3	3	3
G8	Dimensional & Quality Control	3	2	3	4	4	4	3
G9	Lofting Methods	2	3	3	3	3	3	3
	Average	2.4	2.9	3.0	3.2	3.8	3.1	3.1

ORGANIZATION AND OPERATING SYSTEMS		A	B	C	D	E	F	G
H1	Organization of Work	3	2	2	1	2	2	3
H2	Contract Scheduling	2	2	4	3	4	3	2
H3	Steelwork Production Scheduling	2	4	4	4	4	4	3
H4	Outfit Production Scheduling	2	3	3	3	3	3	3
H5	Outfit Installation Scheduling	2	3	3	3	3	3	3
H6	Ship Construction Scheduling	2	3	4	4	4	3	3
H7	Steelwork Production Control	2	4	4	4	4	4	3
H8	Outfit Production Control	2	4	4	4	4	3	3
H9	Outfit Installation Control	2	4	4	4	4	4	3
H10	Ship Construction Control	2	4	4	4	4	4	3
H11	Stores Control	2	2	4	4	4	4	3
H12	Perf. & Efficiency Calculations	1	4	4	4	4	3	4
H13	Computer Applications	2	2	3	3	3	2	3
H14	Purchasing	2	3	3	4	4	4	3
	Average	2.0	3.1	3.6	3.5	3.6	3.3	3.0

Table IV -1 Continued

LEVELS OF SHIPBUILDING TECHNOLOGY IN U.S. SHIPYARDS

U.S. Shipyards

DESIGN, DRAFTING, PRODUCTION ENGINEERING AND LOFTING	H	I	J	K	L	M	N
G1 Ship Design	2	3	2	4	1	1	1
G2 Steelwork Drawing Presentation	1	4	3	3		2	2
G3 Outfit Drawing Presentation	2	3	3	3		2	3
G4 Steelwork Coding System	4	4	4	4		4	4
G5 Parts Listing Procedures	4	4	3	4		4	4
G6 Production Engineering	2	3	2	3	3	2	2
G7 Design for Production	3	3	2	3		2	3
G8 Dimensional & Quality Control	3	3	2	3	4	3	4
G9 Lofting Methods	2	3	3	3-		2	3
Average	2.6	3.3	2.7	3.3	2.7	2.4	2.9
ORGANIZATION AND OPERATING SYSTEMS							
H1 Organization of Work	2	2	1	1	4	2	2
H2 Contract Scheduling	2	2	2	3	4	2	2
H3 Steelwork Production Scheduling	4	4	3	4	4	4	4
H4 Outfit Production Scheduling	3	3	3	3	4	3	3
H5 Outfit Installation Scheduling	3	3	3	3	4	3	3
H6 Ship Construction Scheduling	3	3	3	4	4	3	4
H7 Steelwork Production Control	3	3	1	4	4	4	4
H8 Outfit Production Control	3	2	1	3	4	4	4
H9 Outfit Installation Control	3	2	1	3	4	4	4
H10 Ship Construction Control	3	3	1	4	4	4	4
H11 Stores Control	3	2	2	J	2	3	3
H12 Perf. & Efficiency Calculations	4	4	3	4	4	3	4
H13 Computer Applications	2	2	2	3	1	2	3
H14 Purchasing	3	3	2	3	1	2	3
Average	2.9	2.7	2.0	3.3	3.4	3.1	3.4

Table IV-2

LEVELS OF TECHNOLOGY IN COMPARABLE FOREIGN SHIPYARDS

		Foreign Shipyards							
STEELWORK PRODUCTION		A	B	C	D	E	F	G	H
A1	Plate Stockyard & Treatment	3	3	3	2	3	7	3	3
A2	Stiffener Stockyard & Treatment	3	3	3	2	3	4	3	3
A3	Plate Cutting	3	4	2	3	2	4	4	3
A4	Stiffener Cutting	3	4	2	1	2 .	4	3	3
A5	Plate & Stiffener Forming	3	3	3	2	2	4	3	3
A6	Sub-Assembly	2	4	3	2	2	4	3	3
A7	Flat Unit Assembly	3	4	2	1	2	4	3	3
A8	Curved & Corr. Unit Assembly	2	3	3	1	2	4	3	3
A9	3D Unit Assembly	3	4	2	2	3	4	3	3
A10	Superstructure Unit Assembly	3	3	2	2	3	4	3	3
A11	Outfit Steelwork	2	4	2	2	2	3	3	2
	Average	2.7	3.5	2.5	1.8	2.4	3.9	3.1	2.9
OUTFIT PRODUCTION& STORES									
B1	Pipework	2	2	3	2	1	4	3	2
B2	Engineering	2	2	2	3	2	3	3	2
B3	Blacksmiths	3	2	4	2	1	4	4	3
B5	Sheetmetal		2	2	2	2	3	2	2
B5	Woodworking	(:)	(2)	(2)	(2)	(2)	(2)	(2)	(3)
B6	Electrical	1	3	3	1	2	3	3	3
37	Rigging	1	3	3	3	2	4	3	2
B8	Plant Maintenance	3	3	3	3	3	4	3	2
B9	Garage	3	3	3	2	3	4	3	2
B10	General Storage	2	3	2	2	2	4	3	2
Bll	Auxiliary Storage	2	3	3	1	2	4	3	2
	Average	2.0	2.6	2.8	2.1	2.0	3.7	3.0	2.2
OTHER PRE-ERECTION ACTIVIT1ES									
Cl	Module Building	1	4	3	1	1	4	4	2
C2	Outfit Parts Marshalling	1	3	3	1	1	4	3	2
C3	Pre-erection Outfitting	2	3	3	1	2	4	3	?
C4	Block Assembly	3	4	2	3	2	4	4	2
C5	Unit & Block Storage	3	4	2	1	2	4	4	2
	Average	2.0	3.6	2.6	1.4	1.6	4.0	3.6	2.0

( ) Not included in Average

Table IV-2 Continued

LEVELS OF TECHNOLOGY IN COMPARABLE FOREIGN SHIPYARDS

		Foreign Shipyards							
STEELWORK PROOUCTION		J	K	L	M	N	P	R	S
Al	Plate Stockyard & Treatment	3	3	3	2	3	3	3	4
A2	Stiffener Stockyard & Treatment	3	3	3	2	3	3	3	4
A3	Plate Cutting	4	3	3	3	3	3	3	4
A4	Stiffener Cutting ,	4	3	3	2	3	3	2	4
A5	Plate & Stiffener Forming	3	3	3	3	3	3	3	4
A6	Sub-Assembly	4	2	3	3	2	3	3	3
A7	Flat Unit Assembly	4	2	3	2	3	3	3	4
A8	Curved & Corr. Unit Assembly	3	2	3	2	3	3	3	4
A9	30 Unit Assembly	3	2	3	2	3	3	3	4
A10	Superstructure Unit Assembly	4	2	3	2	3	3	2	4
A11	Outfit Steelwork	3	2	3	2	2	1	3	4
	Average	3.5	2.5	3.0	2	2.8	2.8	2.8	3.9
OUTFIT PRODUCTION & STORES									
BI	Pipework	3	2	2	3	2	2	3	3
B2	Engineering	2	2	3	2	3	2	3	3
B3	Blacksmiths	4	3	4	2	3	3	4	4
B4	Sheetmetal	2	2	3	2	1	2	3	3
B5	Woodworking	(2)	(2)	(2)	(2)	(2)	(3)	(3)	(3)
B6	Electrical	3	1	2	2	3	3	3	3
87	Rigging	3	1	3	3	1	2	3	3
B8	Plant Maintenance	3	2	3	3	2	2	3	4
B9	Garage	3	2	3	3	2	2	3	2
B10	General Storage	2	2	3	2	2	2	3	3
B11	Auxiliary Storage	2	2	3	2	2	2	3	3
	Average	2.7	1.9	2.9	2.4	2.1	2.2	3.1	3.2
OTHER PRE-ERECTION ACTIVITIES									
Cl	Module Building	4	3	3	2	2	2	3		4
C2	Outfit Parts Marshalling	3	2	4	2	2	2	3	.	4
C3	Pre-erection Outfitting	3	3	3	2	2	2	3	4
C4	Block Assembly	4	2	4	2	4	3	3	4
C5	Unit & Block Storage	4	2	4	2	4	3	3		4
	Average	3.6	2.4	3.6	2.0	2.8	2.4	3.0	4.0

Table IV -2 Continued

LEVELS OF TECHNOLOGY IN COMPARABLE FOREIGN SHIPYARDS

SHIP CONSTRUCTION AND OUTFIT INSTALLATION	Foreign Shipyards A	B	C	D	E	F	G	H
D1 Ship Construction	3	4	2	3	2	4	4	2
D2 Erection and Fairing	3	3	3	3	2	4	4	2
D3 Welding	3	3	3	3	2	4	3	2
D4 On-Board Services	3	3	3	3	2	4	3	2
D5 Staging and Access	3	3	3	1	2	4	3	2
D6 Pipework	2	3	3	2	3	3	3	2
D7 Engine Room Machinery	2	3	3	3	3	4	3	2
D8 Hull Engineering	2	3	3	2	3	4	3	2
D9 Sheetmetal Work	2	3	2	2	3	3	3	2
D10 Woodwork	(2)	(3)	(2)	(3)	(3)	(3)	(3)	(2)
D11 Electrical	2	3	3	2	3	4	3	2
D12 Painting	2	4	2	2	2	4	4	3
D13 Testing and Commissioning	2	3	3	3	3	3	3	3
D14 After Launch	3	4	3	2	3	4	3	2
Average	2.5	3.2	2.8	2.4	2.5	3.8	3.2	2.2
LAYOUT AND MATERIALS HANDLING								
El Layout and Material Flow	2	3	3	2	3	4	4	3
E2 Materials Handling	3	3	3	1	2	4	3	3
Average	2.5	3.9	3.0	1.5	2.5	4.0	3.5	3.0
ENVIRONMENT AND AMENITIES								
FI General Environmental Protection	2	3	3	2	2	4	3	3
F2 Lighting and Heating	2	3	2	3	2	3	3	3
F3 Noise, Ventilation & Fume Extr.	2	3	2	3	2	3	3	3
F4 Canteen Facilities	3	3	3	2	3	4	4	2
F5 Uashrooms/W.C.'s/Lockers	2	3	3	2	2	4	4	2
F6 Other Amenities	3	3	3	2	3	4	3	2
Average	2.3	3.0	2.7	2.3	2.3	3.7	3.3	2.5

( ) Not included in average.

Table IV-2 Continued

LEVELS OF TECHNOLOGY IN COMPARABLE FOREIGN SHIPYARDS

	Foreign Shipyards							
SHIP CONSTRUCTION OUTFIT INSTALLATION	J	K	L	M	N	P	R	S
D1 Ship Construction	3	2	4	2	3	3	3	4
D2 Erection and Fairing	3	2	4	3	3	3	3	4
03 Welding	3	2	3	3	3	3	3	4
D4 On-Board Services	3	2	4	3	3	3	4	4
D5 Staging and Access	2	2	4	2	3	3	3	4
D6 Pipework	2	3	3	2	2	3	3	3
D7 Engine Room Machinery	3	3	3	3	2	3	3	4
D8 Hull Engineering	3	2	3	3	2	3	3	4
D9 Sheetmetal Work	2	2	3	2	2	3	3	3
D10 Woodwork	(3)	(2)	(3)	(2)	(2)	(3)	(3)	(3)
D11 Electrical	3	2	3	2	2	3	3	4
D12 Painting	4	2	3	4	2	3	3	3
D13 Testing and Commissioning	3	2	3	3	2	3	3	3
D14 After Launch	3	3	3	2	4	3	3	4
Average	2.8	2.2	3.3	2.6	2.5	3.0	3.1	3.7
LAYOUT AND MATERIALS HANDLING								
El Layout and Material Flow	3	3	4	3	3	3	3	3
E2 Materials Handling	3	2	3	3	3	3	3	3
Average	3.0	2.5	3.5	3.0	3.0	3.0	3.0	3.0
ENVIRONMENT AND AMENITIES								
F1 General Environmental Protection	3	2	4	3	2	3	3	4
F2 Lighting and Heating	3	2	4	3	2	3	3	4
F3 Noise, Ventilation & Fume Extr.	3	2	3	3	2	3	3	4
F4 Canteen Facilities	3	2	4	3	3	2	3	4
F5 Washrooms/W.C. ‘s/Lockers	3	2	4	4	2	2	3	4
F6 Other Amenities	2	2	4	2	3	2	3	4
Average	2.8	2.0	3.8	3.0	2.3	2.5	3.0	4.0

Table IV-2 Continued

LEVELS OF TECHNOLOGY IN COMPARABLE FOREIGN SHIPYARDS

DESIGN, DRAFTING, PRODUCTION ENGINEERING AND LOFTING		Foreign Shipyards							
		A	B	C	D	E	F	G	H
G1	Ship Design	3	3	3	3	3	4	4	3
G2	Steelwork Drawing Presentation	3	3	3	2	1	4	4	3
G3	Outfit Drawing Presentation	2	3	3	2	1	4	4	3
G4	Steelwork Coding Systems	4	4	2	1	3	3	4	4
G5	Parts Listing Procedures	3	3	3	2	1	4	3	3
G6	Production Engineering	3	3	4	2	2	4	4	3
G7	Design for Production	3	3	3	2	3	4	4	3
G8	Dimensional & Quality Control	3	3	3	3	3	4	3	3
G9	Lofting Methods	3	3	3	3	2	4	3	3
	Average	3.0	3.1	3.0	2.2	2.1	3.9	3.7	3.1

ORGANIZATION AND OPERATING SYSTEMS		A	B	C	D	E	F	G	H
H1	Organization of Work	2	3	4	1	2	4	3	3
H2	Contract Scheduling	2	4	2	3	2	4	3	2
H3	Steelwork Production Scheduling	2	4	3	2	3	4	3	4
H4	Outfit Production Scheduling	2	4	3	3	1	4	3	2
H5	Outfit Installation Scheduling	3	4	3	3	3	4	3	3
H6	Ship Construction scheduling	2	4	3	3	2	4	3	4
H7	Steelwork Production Control	3	3	3	3	3	4	3	3
H8	Outfit Production Control	2	3	3	2	2	4	3	2
H9	Outfit Installation Control	2	3	3	3	2	4	3	2
H10	Ship Construction Control	3	3	3	3	2	4	3	3
H11	Stores Control	2	4	3	3	2	4	3	2
H12	Perf. & Efficiency Calculations	3	3	3	2	2	4	3	3
H13	Computer Applications	3	3	3	3	2	4	3	3
H14	Purchasing	3	3	3	3	2	4	3	3
	Average	2.4	3.4	3.0	2.6	2.1	4.0	3.0	2.8

Table IV-2 Continued

LEVELS OF TECHNOLOGY IN COMPARABLE FOREIGN SHIPYARDS

9ESIGN, DRAFTING, PRODUCTION ENGINEERING AND LOFTING		Foreign Shipyards J	K	L	M	N	P	R	S
G1	Ship Design	3	3	4	3	3	3	4	4
G2	Steelwork Drawing Presentation	3	3	4	3	3	3	3	4
G3	Outfit Drawing Presentation	3	3	4	2	3	3	3	4
G4	Steelwork Coding Systems	3	2	4	3	4	4	3	4
G5	Parts Listing Procedures	3	3	4	3	4	3	3	4
G6	Production Engineering	3	2	4	3	3	3	4	4
G7	Design for Production	3	3	4	3	3	3	3	4
G8	Dimensional & Quality Control	3	2	4	3	2	3	4	4
G9	Lofting Methods	4	3	4	3	3	3	3	4
	Average	3.1	2.7	4.0	2.9	3.1	3.1	3.3	4.0

ORGANIZATION AND OPERATING SYSTEMS		J	K	L	M	N	P	R	S
H1	Organization of Work	2	2	4	3	3	3	4	4
H2	Contract Scheduling	3	3	4	3	2	2	3	4
H3	Steelwork Production Scheduling	3	3	4	3	3	4	3	4
H4	Outfit Production Scheduling	3	2	4	3	3	2	3	4
H5	Outfit Installation Scheduling	3	3	4	3	3	3	3	4
H6	Ship Construction Scheduling	3	2	4	3	2	3	3	4
H7	Steelwork Production Control	3	3	4	3	4	3	3	4
H8	Outfit Production Control	3	2	4	3	4	2	3	4
H9	Installation Control	3	3	4	3	3	3	3	4
H10	Ship Construction Control	3	2	4	3	2	3	3	4
H11	Stores Control	3	2	4	3	3	2	4	4
H12	Perf. & Efficiency Calculations	3	2	4	3	2	3	3	4
H13	Computer Applications	3	2	4	3	3	3	3	4
H14	Purchasing	4	3	4	3	3	3	3	4
	Average	3.0	2.4	4.0	3.0	2.9	2.8	3.1	4.0

Table IV -3

LEVELS OF TECHNOLOGY IN THIRTEEN U.S. SHIPYARDS BY LEVEL

		Level			
STEELWORK PRODUCTION	Ave	1	2	3	4
Al Plate Stockyard & Treatment	2.7	0	4	9	0
A2 Stiffener Stockyard & Treatment	2.2	1	8	4	0
A3 Plate Cutting	3.5	0	0	7	6
A4 Stiffener Cutting	1.5	6	7	0	0
A5 Plate & Stiffener Forming	2.2	1	8	4	0
A6 Sub-Assembly	2.0	1	11	1	0
A7 Flat Unit Assembly	2.3	2	5	6	0
A8 Curved & Corr. Unit Assembly	2.2	1	8	4	0
A9 30 Unit Assembly	2.1	1	10	2	0
A10 Superstructures Unit Assembly	2.3	0	9	4	0
All Outfit Steelwork	1.8	2	11	0	0
Average	2.3				
OUTFIT PRODUCTION & STORES					
B1 Pipework	2.0	1	11	1	0
B2 Engineering	1.9	3	8	2.0	
B3 Blacksmiths	3.9	0	0	1	12
B4 Sheetmetal	2.1	2	8	3	0
B5 Woodworking					
B6 Electrical	2.3	0	10	2	1
B7 Rigging	2.5	0	8	4	1
B8 Plant Maintenance	2.4	1	7	4	1
B9 Garage	3.1	0	3	6	4
B10 General Storage	2.3	1	7	5	0
B11 Auxiliary Storage	3.0	0	0	13	0
Average	2.6				
OTHER PRE-ERECTION ACTIVITIES					
Cl Module Building	1.6	7	4	2	0
C2 Outfit Parts Marshaling	1.9	3	8	2	0
C3 Pre-erection Outfitting	2.1	3	6	4	0
C4 Block Assembly	2.2	2	7	4	0
C5 Unit and Block Storage	2.4	4	2	5	2
Average	2.0				

Table IV-3 Continued

LEVELS OF TECHNOLOGY IN THIRTEEN U.S. SHIPYARDS BY LEVEL

SHIP CONSTRUCTION AND OUTFIT INSTALLATION	AVE	Level 1	2	3	4
D1 Ship Construction	2.2	3	6	2	2
D2 Erection and Fairing	2.3	0	9	4	0
D3 Welding	2.3	0	9	4	0
D4 On-Board Services	2.5	1	4	8	0
D5 Staging and Access	2.2	2	7	4	0
D6 Pipework	2.4	0	8	5	0
D7 Engine Room Machinery	2.5	1	4	8	0
D8 Hull Engineering	2.2	2	6	5	0
D9 Sheetmetal Work	3.2	0	1	9	3
010 Woodwork					
D11 Electrical	2.4	1	6	6	0
012 Painting	2.5	1	5	6	1
D13 Testing and Commissioning	3.5	1	0	4	8
D14 After Launch	2.6	1	3	9	0
Average	2.5				
LAYOUT AND MATERIALS HANDLING					
El Layout and Material Flow	2.5	0	7	5	1
E2 Materials Handling	2.5	0	7	6	0
Average	2.5				
ENVIRONMENT AND AMENITIES					
F1 General Environmental Protection	2.2	0	10	3	0
F2 Lighting and Heating	2.3	0	9	4	0
F3 Noise, Ventilation & Fume Extr.	2.3	0	9	4	0
F4 Canteen Facilities	2.1	3	7	2	1
F5 Washrooms/W.C. ‘s/Lockers	2.2	0	11	2	0
F5 Other Amenities	1.2	11	1	1	0
Average	2.0				

Table IV-3 Continued

LEVELS OF TECHNOLOGY IN THIRTEEN U.S. SHIPYARDS BY LEVEL

DESIGN, DRAFTING, PRODUCTION ENGINEERING AND LOFTING		Ave	Level 1	2	3	4
G1	Ship Design	2.6	2	4	4	3
G2	Steelwork Drawing Presentation	2.7	1	4	6	2
G3	Outfit Drawing Presentation	2.8	0	3	9	1
G4	Steelwork Coding Systems	3.9	0	0	1	12
G5	Parts Listing Procedures	3.6	0	1	3	9
G6	Production Engineering	2.5	0	7	5	1
G7	Design for Production	2.7	0	5	7	1
G8	Dimensional & Quality Control	3.2	0	2	7	4
G9	Lofting Methods	2.8	0	3	10	0
	Average	3.0				

ORGANIZATION AND OPERATING SYSTEMS		Ave	1	2	3	4
H1	Organization of Work	1.9	3	8	2	0
H2	Contract Scheduling	2.5	0	8	3	2
H3	Steelwork Production Scheduling	3.7	0	1	2	10
H4	Outfit Production Scheduling	2.9	0	1	12	o
H5	Outfit Installation Scheduling	2.9	o	1	12	0
H6	Ship Construction Scheduling	3.3	0	1	7	5
H7	Steelwork Production Control	3.4	1	1	3	8
H8	Outfit Production Control	3.2	1	2	4	6
H9	Outfit Installation Control	3.2	1	2	3	7
H10	Ship Construction Control	3.4	1	1	3	8
H11	Stores Control	3.1	0	4	4	5
H12	Perf. & Efficiency Calculations	3.5	1	0	3	9
H13	Computer Applications	2.5	0	7	6	0
H14	Purchasing	3.0	0	3	7	3
	Average	3.0				

Table IV-4 Continued

LEVELS OF TECHNOLOGY IN SIXTEEN FOREIGN SHIPYARDS BY LEVEL

	Ave	Level 1	2	3	4
STEELWORK PRODUCTION					
Al Plate Stockyard & Treatment	3.0	0	2	12	2
A2 Stiffener Stockyard & Treatment	3.0	0	2	12	2
A3 Plate Cutting	3.2	0	2	9	5
A4 Stiffener Cutting	2.9	1	4	7	4
A5 Plate & Stiffener Forming	3.0	0	2	12	2
A6 Sub-Assembly	2.9	0	5	8	3
A7 Flat Unit Assembly	2.9	1	4	7	4
A8 Curved & Corr. Unit Assembly	2.8	1	4	9	2
A9 3D Unit Assembly	2.9	0	4	9	3
A10 Superstructure Unit Assembly	2.9	0	5	8	3
All Outfit Steelwork	2.5	1	8	5	2
Average	2.9				
OUTFIT PRODUCTION AND STORES					
B1 Pipework	2.4	1	8	6	1
B2 Engineering	2.4	0	9	7	0
B3 Blacksmiths	3.1	1	3	5	7
94 Sheetmetal Work	2.1	2	10	4	0
B5 Woodworking		0	11	5	0
B6 Electrical	2.4	3	3	10	0
B7 Rigging	2.5	3	3	9	1
B8 Maintenance	2.9	0	4	10	2
B9 Garage	2.8	0	5	10	1
Blo General Storage	2.4	0	10	5	1
B11 Auxiliary Storage	2.4	1	8	6	1
Average	2.5				
OTHER PRE-ERECTION ACTIVITIES					
cl Module Building	2.7	3	4	4	5
C2 Outfit Parts Marshaling	2.5	3	5	5	3
C3 Pre-erection Outfitting	2.6	1	6	7	2
C4 Block Assembly	3.1	0	5	4	7
C5 Unit and Block Storage	3.0	1	5	3	7
Average	2.8				

Table IV-4 Continued

LEVELS OF TECHNOLOGY IN SIXTEEN FOREIGN SHIPYARDS BY LEVEL

SHIP CONSTRUCTION AND OUTFIT INSTALLATION	Ave.	Level 1	2	3	4
D1 Ship Construction	3.0	0	5	6	5
D2 Erection and Fairing	3.1	0	3	9	4
D3 Welding	2.9	0	3	11	2
D4 On-Board Services	3.1	0	3	9	4
D5 Staging and Access	2.8	1	5	7	3
D6 Pipework	2.6	0	6	10	0
D7 Engine Room Machinery	2.9	0	3	11	2
D8 Hull Engineering	2.8	0	5	9	2
D9 Sheetmetal Work	2.5	0	8	8	0
D10 Woodwork		0	6	10	0
D11 Electrical	2.8	0	6	8	2
D12 Painting	2.9	0	6	5	5
D13 Testing and Commissioning	2.8	0	3	13	0
D14 After Launch	3.1	0	3	9	4
Average	2.9				
LAYOUT AND MATERIALS HANDLING					
E1 Layout and Material Flow	3.1	0	2	11	3
E2 Materials Handling	2.8	1	2	12	1
Average	3.0				
Environment AND AMENITIES					
F1 General Environmental Protection	2.9	0	5	8	3
F2 Lighting and Heating	2.8	0	5	9	2
F3 Noise, Ventilation & Fume Extr.	2.8	0	5	10	1
F4 Canteen Facilities	3.0	0	4	3	4
F5 Washrooms/W.C.'s/Lockers	2.9	0	7	4	5
F6 Other Amenities	2.8	0	6	7	3
Average	2.9				

Table IV-4 Continued

LEVELS OF TECHNOLOGY IN SIXTEEN FOREIGN SHIPYARDS BY LEVEL

DESIGN, DRAFTING, PRODUCTION ENGINEERING AND LOFTING		Ave.	Level 1	2	3	4
G1	Ship Design	3.3	0	0	11	5
G2	Steelwork Drawing Presentation	3.1	1	1	10	4
G3	Outfit Drawing Presentation	2.9	1	3	8	4
G4	Steelwork Coding Systems	3.5	1	2	5	8
G5	Parts Listing Procedures	3.1	1	1	10	4
G6	Production Engineering	3.2	0	3	7	6
G7	Design for Production	3.2	0	1	11.	4
G8	Dimensional & Quality Control	3.1	0	2	10	4
G9	Lofting Methods	3.2	0	1	11	4
	Average	3.2				

ORGANIZATION AND OPERATING SYSTEMS		Ave.	1	2	3	4
HI	Organization of Work	2.9	1	4	6	5
H2	Contract Scheduling	2.9	0	6	6	4
H3	Steelwork Production Scheduling	3.2	0	2	8	6
H4	Outfit Production Scheduling	2.9	1	4	7	4
H5	Outfit Installation Scheduling	3.2	0	0	12	4
H6	Ship Construction Scheduling	3.1	0	4	7	5
H7	Steelwork Production Control	3.2	0	0	12	.4
H8	Outfit Production Control	2.9	0	6	6	4
H9	Outfit Installation Control	3.0	0	3	10	3
H10	Ship Construction Control	3.0	0	3	10	3
H11	Stores Control	3.0	0	5	6	5
H12	Perf. & Efficiency Calculations	2.9	0	4	9	3
H13	Computer Applications	3.1	0	2	11	3
H14	Purchasing	3.2	0	1	11	4
	Average	3.0				

IV-20

Table IV -5

LEVELS OF TECHNOLOGY IN U.S. SHIPYARDS BY LEVEL IN PERCENT

		% Distribution Level 1	2	3	4
STEELWORK PRODUCTION					
Al	Plate Stockyard & Treatment	0	31	69	0
A2	Stiffener Stockyard & Treatment	8	62	31	0
A3	Plate Cutting	0	0	54	46
A4	Stiffener Cutting	46	54	0	0
A5	Plate & Stiffener Forming	8	62	31	0
A6	Sub-Assembly	8	85	8	0
A7	Flat Unit Assembly	15	38	46	0
A8	Curved & Corr. Unit Assembly	8	62	31	0
A9	3D Unit Assembly	8	77	15	0
Al0	Superstructure Unit Assembly	0	69	31	0
A11	Outfit Steelwork	15	85	0	0
OUTFIT PRODUCTION & STORES					
B1	Pipework	8	85	8	0
B2	Engineering	23	62	15	0
B3	Blacksmiths	0	0	8	92
B4	Sheetmetal	15	62	23	0
B5	Woodworking				
B6	Electrical	0	77	15	8
B7	Rigging	0	62	31	8
B8	Plant Maintenance	8	54	31	8
B9	Garage	0	23	46	31
B10	General Storage	8	54	38	0
Bll	Auxiliary Storage	0	0	100	0
OTHER PRE-ERECTION ACTIVITIES					
C1	Module Builidng	54	31	15	0
C2	Outfit Parts Marshalling	23	62	15	0
C3	pre-erection Outfitting	23	46	31	0
C4	Block Assembly	31	15	38	15
C5	Unit & Block Storage	0	54	46	0

Table IV-5 Continued

LEVELS OF TECHNOLOGY IN U.S. SHIPYARDS BY LEVEL IN PERCENT

		% Distribution Level			
SHIP CONSTRUCTION AND OUTFIT INSTALLATION		1	2	3	4
D1	Ship Construction	23	46	15	15
D2	Erection and Fairing	0	69	31	0
D3	Welding	0	69	31	0
D4	On-Board Services	8	31	62	0
D5	Staging and Access	15	54	31	0
D6	Pipework	0	62	38	0
D7	Engine Room Machinery	8	31	62	0
D8	Hull Engineering	15	46	38	0
D9	Sheetmetal Work	0	8	69	23
D10	Woodwork				
D11	Electrical	8	46	46	0
D12	Painting	8	38	46	8
D13	Testing and commissioning	8	0	31	62
D14	After Launch	8	23	69	0
LAYOUT AND MATERIALS HANDLING					
El	Layout and Material Flow	0	54	38	8
E2	Materials Handling	0	54	46	0
ENVIRONMENT AND AMENITIES					
FI	General Environmental Protection	0	77	23	0
F2	Lighting and Heating	0	69	31	0
F3	Noise, Ventilation & Fume Extr.	0	69	31	0
F4	Canteen Facilities	23	54	15	8
F5	Washrooms/W.C. ‘s/Lockers	0	85	15	0
F6	Other Amenities	85	8	8	0

Table IV-5 Continued

LEVELS OF TECHNOLOGY IN U.S. SHIPYARDS BY LEVEL IN PERCENT

DESIGN, DRAFTING, PRODUCTION ENGINEERING AND LOFTING		% Distribution Level 1	2	3	4
G1	Ship Design	15	31	31	23
G2	Steelwork Drawing Presentation	8	31	46	15
G3	Outfit Drawing Presentation	0	23	69	8
G4	Steelwork Coding Systems	0	0	8	92
G5	Parts Listing Procedures	0	8	23	69
G6	Production Engineering	0	54	38	8
G7	Design for Production	0	38	54	8
G8	Dimensional & Quality Control	0	15	54	31
G9	Lofting Methods	0	23	77	0
ORGANIZATION AND OPERATING SYSTEMS					
H1	Organization of Work	23	62	15	0
H2	Contract Scheduling	0	62	23	15
H3	Steelwork production scheduling	0	8	15	77
H4	Outfit Production Scheduling	0	8	92	0
H5	Outfit Installation Scheduling	0	8	92	0
H6	Ship Construction Scheduling	0	8	54	38
H7	Steelwork Production Control	8	8	23	62
H8	Outfit Production Control	8	15	31	46
H9	Outfit Installation Control	8	15	23	54
H10	Snip Construction Control	8	8	23	62
H11	Stores Control	0	31	31	38
H12	Perf. & Efficiency Calculations	8	0	23	69
H13	Computer Applications	0	54	46	0
H14	Purchasing	0	23	54	23

Table IV-6

LEVELS OF TECHNOLOGY IN FOREIGN SHIPYARDS BY LEVEL IN PERCENT

	% Distribution Level			
	1	2	3	4
STEELWORK PRODUCTION				
A1 Plate Stockyard & Treatment	0	12	75	12
A2 Stiffener Stockyard & Treatment	0	12	75	12
A3 Plate Cutting	0	12	56	31
A4 Stiffener Cutting	6	25	44	25
A5 Plate & Stiffener Forming	0	12	75	12
A6 Sub-Assembly	0	31	50	19
A7 Flat Unit Assembly	6	25	44	25
A8 Curved & Corr. Unit Assembly	6	25	56	12
A9 3DUnit Assembly	0	25	56	19
A10 Superstructure Unit Assembly	0	31	50	19
A11 Outfit Steelwork	6	50	31	12
OUTFIT PRODUCTION & STORES				
B1 Pipework	6	50	38	6
B2 Engineering	0	56	44	0
B3 Blacksmiths	6	19	31	44
B4 Sheetmetal	12	62	25	0
B5 Woodworking	0	69	31	0
B6 Electrical	19	19	62	0
B7 Rigging	19	19	56	6
B8 Plant Maintenance	0	25	62	12
B9 Garage	0	31	62	6
B10 General Storage	0	62	31	6
B11 Auxiliary Storage	6	50	38	6
OTHER PRE-ERECTION ACTIVITIES				
cl Module Building	19	25	25	31
C2 Outfit Parts Marshalling	19	31	31	19
C3 Pre-erection Outfitting	6	38	44	12
C4 Mock Assembly	0	31	25	44
C5 Unit & Block Storage	6	31	19	44

Table IV-6 Continued

LEVELS OF TECHNOLOGY IN FOREIGN SHIPYARDS BY LEVEL IN PERCENT

	% Distribution Level			
SHIP CONSTRUCTION AND OUTFIT INSTALLATION	1	2	3	&
D1 Ship Construction	0	31	38	31
D2 Erection and Fairing	0	19	56	25
D3 Welding	0	19	69	12
D4 On-Board Services	0	19	59	25
D5 Staging and Access	6	31	44	19
D6 Pipework	0	38	62	0
D7 Engine Room Machinery	0	19	69	12
D8 Hull Engineering	0	31	56	12
D9 Sheetmetal Work	0	50	50	0
D10 Woodwork	0	38	62	0
D11 Electrical	0	38	50	12
D12 Painting	0	38	31	31
D13 Testing and Commissioning	0	19	S1	0
D14 After Launch	0	19	56	25
LAYOUT AND MATERIALS HANDLING				
El Layout and Material Flow	0	12	69	19
E2 Materials Handling	6	12	75	6
ENVIRONMENT AND AMENITIES				
F1 General Environment Protection	0	31	50	19
F2 Lighting and Heating	0	31	56	12
F3 Noise, Ventilation & Fume Extr.	0	31	62	6
F4 Canteen Facilities	0	25	50	25
F5 Washrooms/W.C. 's/Lockers	0	44	25	31
F6 Other Amenities	0	38	44	19

Table IV-6 Continued

LEVELS OF TECHNOLOGY IN FOREIGN SHIPYARDS BY LEVEL IN PERCENT

	% Distribution Level			
DESIGN, DRAFTING, PRODUCTION ENGINEERING AND LOFTING	1	2	3	4
G1 Ship Design	0	0	69	31
G2 steelwork Drawing Presentation	6	6	62	25
G3 Outfit Drawing Presentation	6	19	50	25
G4 Steelwork Coding Systems	6	12	31	50
G5 Parts Listing Procedures	6	6	62	25
G6 Production Engineering	0	19	44	38
G7 Design for Production	0	6	69	25
G8 Dimensional & Quality Control	0	12	62	25
G9 Lofting Methods	0	6	69	25
ORGANIZATION AND OPERATING SYSTEMS				
H1 Organization of Work	6	25	38	31
H2 Contract Scheduling	0	38	38	25
H3 Steelwork Production Scheduling	0	12	50	38
H4 Outfit Production Scheduling	6	25	44	25
H5 Outfit Installation Scheduling	0	0	75	25
H6 Ship Construction	0	25	44	38
H7 Steelwork Production Control	0	0	75	25
H8 Outfit Production Control	0	38	38	25
H9 Outfit Installation Control	0	19	62	19
H10 Ship Construction Control	0	19	62	19
H11 Stores Control	0	31	33	31
H12 Perf. & Efficiency Calculations	0	25	56	19
H13 Computer Applications	0	12	69	19
H14 Purchasing	0	6	69	25

V. SUMMARY

V SUMMARY

The primary objective of this survey is to provide shipyard management and the government comprehensive information on which to base and evaluate plans for improving shipbuilding technology.

1. U.S. SHIPYARDS EMPLOY LOWER LEVELS OF TECHNOLOGY THAN FOREIGN SHIPYARDS

U.S. shipyards, on an average, are using a lower level of technology than foreign shipyards in six of the eight major categories studied.

In Category B, Outfit Production and Stores, U.S. shipyards are slightly superior to the foreign shipyards. It is believed this is due to the amount of repair work and naval construction work done in many of the U.S. shipyards.

In Category H, Organization and Operating Systems, U.S. shipyards are superior in eight out of the 14 elements. This superiority is again related to the requirements for naval construction and doing work for the government in general.

The survey shows that of the 70 elements examined, foreign shipyards, based on overall averages, employ a higher level of technology in 51 cases. When shipyard size is considered, the larger the shipyard the higher the technology. This is true for both U.S. and foreign shipyards.

The smaller of the major U.S. shipyards tend to be more on a par with their foreign counterparts. This may be due, in part, to the requirements inherent in sophisticated U.S. naval construction while their foreign counterparts are more commercially oriented, building less complex ships. However, neither group is highly advanced. In fact, most of the smaller shipyards have not adopted high technology in many of the full range of elements.

The postmarked differences in technology levels are found in the medium sized shipyards that account for nearly half of the major U.S. shipyards. This may be due in large part to the wide range of ship types that U.S. shipbuilders must build to stay alive. Also, the U.S. market, being primarily domestic, has not required construction of sufficient numbers of similar ships to encourage shipyard specialization and investment in high output technology.

2. LOW TECHNOLOGY WAS FOUND IN CRITICAL AREAS IN U.S. SHIPYARDS

Low technology was found in 16 critical areas which are either labor intensive or labor sensitive. These areas fall into five general categories:

- steel assembly
- pre-erection outfitting
- ship erection
- production engineering
- organization of work

3. <u>CRITICAL AREAS OF LOW TECHNOLOGY ARE PRIMARILY MANAGEMENT AND SYSTEM ORIENTED</u>

A review of the 16 critical elements indicated that improvement in nine areas would not require more than minor capital investment, but would depend primarily upon management initiative. The elements in this category are:

C1 Module Building
C2 Outfit Parts Marshalling
C3 Pre-erection Outfitting
D2 Erection and Fairing
D4 On-board Services
D8 Hull Engineering
Gl Ship Design
G6 Production Engineering
H1 Organization of Work

The last element, Hi-organization of Work, is one which management and labor must solve together.

A second group of five elements would require a modest capital investment in order to improve technology in addition, of course, to a management decision to move in that direction.

A6 Sub-assembly
A8 Curved Unit Assembly
A9 3 D Unit Assembly
D3 Welding
Fl General Environmental Protection

To improve technology in the last two of the critical elements, C4-Block Assembly and D1-Ship Construction a major investment would be required by most shipyards.

4. TECHNOLOGY LEVELS ARE VERY LOW IN FIVE ADDITIONAL AREAS

There are five elements, not previously discussed, for which U.S. shipyard technology level averages are 2.0 or below. These elements are:

	Stiffener Cutting
A11	Outfit Steelwork
B1	Pipework
B2	Engineering (Machining)
F6	Other Amenities

Sixty one of the sixty five level assignments made for these five elements in the 13 U.S. shipyards surveyed were assigned Level 1 or Level 2. This suggests the possibility of making substantial improvements in these areas.

5. U.S. SHIPYARDS ARE FOUND TO BE OUTSTANDING IN SOME AREAS

Of the 70 elements measured, U.S. shipyards were found, on the average, to be employing more advanced technology than their foreign counterparts in 16 instances.

In nine of these instances which are considered particularly significant, the average U.S. shipyard is more advanced by three tenths of a technology level than the average of the foregin shipyards. The specific elements are:

A3	Plate Cutting
B11	Auxiliary Storage
D13	Testing and Commissioning
	Steelwork Coding Systems
G5	Parts Listing Procedures
H3	Steelwork Production Scheduling
H8	Outfit Production Control
H9	Outfit Installation Control
H10	Ship Construction Control

6. U.S. SHIPYARD MANAGEMENT IS AGGRESSIVELY IMPLEMENTING HIGHER TECHNOLOGIES

A ground rule for this survey was to observe what was being done at the time, mot plans and expectations. Many shipyards are, however, implementing technology improvements over a wide range of activities. These include interactive graphics in conjunction with computer aided design, module building, preoutfitting, construction of larger units and blocks, painting, welding, etc. These improvements will certainly raise technology levels in the future.

7. THE SURVEY PROCEDURE PROVIDED A VALID COMPARISON BETWEEN U.S. AND FOREIGN SHIPYARDS

The concept of comparing shipbuilding technology on an international basis raised some very appropriate questions as to feasibility. The biggest question was whether different surveyors using the same standards could develop truly comparable results. Another substantial question was whether or not the standards for comparison of shipbuilding practices would be truly applicable to shipyards in different countries.

(1) The Technology Standards are Realistic and can be Consistently Applied by Different Trained Surveyors

The results obtained by cross-grading survey notes between U.S. surveyors and, then, from the review of these notes and grades with the British engineers that surveyed the foreign shipyards, showed a very close agreement with the original

technology levels set by the U.S. surveyors. From this experience, it is the opinion of the MEL and APA surveyors that the following conclusions are valid:

- o That shipyard-wise people can learn and apply the system in a short time
- o That different surveyors get the same answer in checking results
- o That the note-taking system was adequate to enable the foreign shipyard surveyors to verify levels set by the U.S. shipyard surveyors

(2) The 1978 Survey Results Could be Related to Future Surveys

The survey procedures and standards are such that a future survey, say five years from now, could readily be made and compared to the 1978 survey. If there are new advancements in technology that come into use between surveys they can be described in a more advanced level, say Level 5. Follow on surveys, therefore, could measure future technological trends.

(3) The Survey Technique Does Not Cover All the Factors Which Affect Productivity

- o The survey process does not perform an economic feasibility study on the cost benefits of using more advanced technology. Rather, one of the major purposes of the survey is to give shipyard managers a comparative overview of their shipbuilding opera-

tions which will identify areas where further analysis and review may be warranted.

- o The survey does give a good overview of the quality of the “tools” management and labor have available to them to build ships. The survey does not reveal how well these “tools” are used. Many shipyards are highly productive through effective management and a motivated workforce even though high technology is not used.
- o It is believed, however, that everything else being equal, the results of this survey will give the shipbuilding industry and the government a better understanding of a major factor affecting shipbuilding productivity.

8. A&P APPLEDORE HAS REVIEWED THE SURVEY NOTES AND IS OF THE OPINION THAT THE SURVEY HAS GIVEN A CLEARER PICTURE OF U.S. SHIPBUILDING PRACTICES RELATIVE TO THOSE OF THE LEADING OVERSEAS SHIPYARDS

A&P Appledore (London) Ltd. spent a period of several weeks reviewing and comparing the survey notes on U.S. shipyards with its survey results on foreign shipyards.

As a result of this review APA has developed the following observations on each of the eight shipbuilding categories.

(1) <u>Steel Work Production, Category A</u>

With the exception of the plate cutting area, the levels of technology found in the U.S. yards were considerably lower than in the foreign yards. whilst a difference was expected due to the opportunity most of the foreign yards have had to undertake series production and also due to the high priority they have placed on design for production/production engineering aspects, the magnitude of the difference was greater than expected.

U.S. yards have clearly taken advantage of advances in plate cutting technology. However, they have seriously neglected the stiffener cutting side.

Whilst the variety and nature of the product inmost U.S. yards does not justify the widespread application of a very high degree of mechanisation and automation, there is a definite need to upgrade the technology in sub-assembly and assembly. In particular this implies:

- The adoption of the workstation concept of organization.
- The introduction of purpose designed handling and manipulation equipment.
- The extensive use of more sophisticated skids and jigs.
- The introduction of new hydraulic and mechanical fairing systems.

An increase in the proportion of semi automatic and automatic welding.

(2) Outfit Production Stores, Category B

It was surprising that in pipework, engineering, steel metal work and electrical there were few U.S. facilities with a level of technology above Level 2. This generally reflects a lack of well organized, large batch production shops with up-to-date machinery and handling equipment, producing standard items. In some yards this is explained by the use of bought in items or subcontract but in many cases it would appear to be the result of a low level of investment over a number of years. These important outfit production functions would greatly benefit from investment in new equipment and methods in all but the few yards with a very low level of output.

(3) Other Pre-Erection Activities, Category C

Very significant differences were found between the U. S. and foreign yards in all the five elements in the group. Two principal objectives in carrying out the first four of the elements, namely, module building, outfit parts marshalling, pre-erection outfitting and block assembly, are first, to reduce the overall work content in the ship, and second, to reduce the work content on the berth or

building dock. Both of these are achieved by adopting techniques which enable work to be effectively carried out earlier in the shipbuilding cycle in, as far as possible, workshop conditions.

During the sixties and early seventies there was clearly a great deal of pressure on many of the foreign yards selected for this survey to adopt the techniques in this group to improve efficiency, reduce cycle times and increase overall output. Nowadays the emphasis is on low cost productivity improvements. The techniques are sound in almost any shipbuilding situation and can generally be upgraded without massive capital investment.

(4) Ship Construction and Installation, Category Cl

There were no great surprises in this group. Tne largest differences are found in ship construction, erection and fairing, welding, on-board services, staging and access, hull engineering and after launch. Unfortunately in most of these areas not only are radical changes in methods and attitudes required to upgrade technology but. also significant capital investment is needed.

(5) Layout and Materials Handling, Category E

The U.S. yards show a number of examples of poor design of layout and material flow patterns, and inappropriate and outdated materials handling methods. Significant

improvements in materials handling and flow can be achieved without huge capital investment.

(6) Environment and Amenities, Category F

The low averages in elements 1, 2 and 3 of this group generally reflect the large number of old buildings in many U.S. yards which offer below average working conditions.

In the case of elements 4, 5 and 6, in many European and Japanese shipyards high standard facilities are often either demanded by the workforce or are provided by the company for other reasons.

(7) Design, Drafting, Production Engineering and Lofting, Category G.

In ship design the difference is largely explained by the fact that some U.S. yards use outside naval architects and consultants rather than having in-house facilities as found in all the foreign yards surveyed. This does not necessarily impair the efficiency of the design function although this may be one of the reasons why the design for production and production engineering ratings in the U.S. yards were lower than their foreign counterparts. Design for production needs to be applied not only at the initial design stage but right through design development and detailing. This can only be achieved when

all the relevant shipyard departments believe in the benefits of production orientated design and apply it with conviction and persistence.

(8) Organization and Operating Systems, Category H

Work station organization is not common in the U.S. yards. The point which was of greatest concern in this part Of the work related to the difference between cost and budgetary control and production control. The problem basically is as follows. Most yards appear to have soundly based recording and control systems, some of which will use fairly advanced computer systems and look very impressive. These systems do not, however, of themselves, improve production scheduling which would result in improved machine loading packages. U.S. shipyards need competent teams of industrial engineers and work analysts dedicated to the detailed planning of work at shop floor level.

9. THE SURVEY FINDINGS SUGGEST THAT OPPORTUNITIES FOR IMPROVED SHIPBUILDING PERFORMANCE STILL EXIST EVEN IN TODAY'S DEPRESSED SHIPBUILDING MARKET

(1) The system used in this survey provides a comprehensive overview of each shipyard giving the shipyard managers an additional tool to supplement their own efforts to effect improvements.

(2) The survey results do disclose certain areas where a cooperative effort by government and industry could benefit both parties.

(3) There are indications that progress is being made in the preoutfitting area, but there is room for additional effort.

(4) There are some modules being built but, again, there is room for additional work. Several possible avenues may be available. These include ordering more complete units from suppliers, and specifying interface connections on modules complete with foundations even before the exact configuration of specific items of equipment is known.

(5) The structure of this survey technique does not parallel typical estimating systems. This, the framework for cross-check is provided.

(6) In some instances, particularly in the production of outfit items, the equipment needed for higher technology levels is expensive and might well be underutilized. There may be cost effective opportunities in establishing central capability serving the industry or indeveloping sub-contract sources in other industries.

(7) A number of the high technology foreign shipyards have invested heavily in specialized facilities

not suitable for a wide product mix with few similar ships. With the current depressed state of world shipbuilding, an opportunity to leapfrog these highly specialized foreign shipyards with more versatile U.S. shipyards may be present.

(8) There should be opportunities to develop Level 5 technology using the present Level 4 standards as a stepping off point. A survey of other industries with such elements as pre-erection outfitting and module building in mind could be useful.

(9) The evidence that the foreign shipyards considered to be highly efficient have paid considered attention to working conditions suggests the possibility of opportunities in this area to enhance worker morale and reduce turnover.

APPENDIX A

DESCRIPTION OF THE 72 SHIPBUILDING ELEMENTS

A STEELWORK PRODUCTION

A1. PLATE STOCKYARD AND TREATMENT

Description: The storage, handling, treatment and control of plate from receipt to delivery to the cutting area.

Points Evaluated: Method of storage, Handling, Treatment, Manning, Control.

A2. STIFFENERS

Description: The storage, handling, treatment and control of stiffeners from receipt to delivery to the cutting area.

Points Evaluated: Method of storage, Handling, Treatment, Manning, Control.

A3. PLATE CUTTING

Description: Cutting by all means large rectangular and non-rectangular plates - large and small internals - floors - longitudinals - webs - etc.

Points Evaluated: Marking, Handling, Cutting, Accuracy.

A4. STIFFENER CUTTING

Description: Cutting by all means rolled shapes, e.g., angles, H beams, channels, I beams.

Points Evaluated: Marking, Handling, Cutting, Accuracy.

A5. PLATE AND STIFFENER FORMING

Description: The process used to effect single or double curvature.

Points Evaluated: Forming process, Technical Info Transfer, Handling, Accuracy.

.46. SUB-ASSEMBLY

Description: Assembly of parts of a main unit. It will include putting face plates on webs, installing brackets and stiffeners on floors, longitudinal and foundations, etc.

Points Evaluated: Workstation definition, Mat Handling, Mat Marking, Jigs, Welding, Fairing, Storage, Material F1 ow.

A7 . FLAT UNITASSEMBLY

Description: This includes the welding together of flat plates to form flat sections of shell, deck, bulkhead, tank top, etc. It included attachment of stiffeners, floors, webs and longitudinal.

Points Evaluated: Workstation definition, Material Handling, Material Positioning, Welding, Fairing, Major Unit Build Up, Storage.

A8 . CURVED AND CORRUGATED UNIT ASSEMBLY

Description: This is similar in nature to flat assemblies: including single and double curved shell units, bilge, corrugated bulkheads.

Points Evaluated: Workstation Definition, Material Handling, Jigs & Supports, !+elding, Fairing, Storage.

A9 3D UNIT ASS&YBLY

Description: This refers to units that are three dimensional and totally enclosed. It will include “ double bottom units, bow and stern units, tank units, etc.

Points Evaluated: Workstation Definition, Material Handling, Jigs i? Supports, welding, Storage, Capacity.

A10. SUPERSTRUCTURE UNIT ASSEMBLY

Description: This includes flat panels for decks and sides as well as three dimensional self-supporting units.

Points Evaluated: Workstation Definition, Material Handling, Jigs and Supports, Welding, Fairing, Storage, Capacity.

All. OUTFIT STEEL

Description: This includes the fabrication of masts, kingposts, hatches, foundations, bulwarks, ladders, small tanks, pipe supports, etc.

Points Evaluated: Workstation Definition, Mat Handling, Mat Marking, Jigs, Welding, Fairing, Storage, Material flow.

B OUTFIT PRODUCTION AND STORAGE

B1 . PIPEWORK

Description: Fabrication (manufacture) of pipe and fittings bending, flanging, priming, etc.) prior to installation.

Points Evaluated: Storage, Welding, Bending & Fabricating.

B2 . ENGINEERING (MACHINE SHOP)

Description: Manufacture of items needed to install main, auxiliary and hull machinery; possible manufacture selected items (e.g., turn shaft, mill sea chests).

Points Evaluated: Machine Tool Arrangement, Work Piece Handling & Storage.

B3 . BLACKSMITHS (FORGE)

Description: Production of all shipyard supplied forged items required for installation.

Points Evaluated: Source of forgings, Shop Capability.

24. SHEETMETAL WORK

Description: Manufacture of furniture, galley equipment, ducts, wire mesh screens, etc. Limited to about 1/8" stock.

Points Evaluated: ,Machine Tools/Arrangement, Material Handling & Storage.

B5 . WOODWORKING

Description: Manufacture of wood products including furniture, trim, laminates, supports and blocks.

Points Evaluated: Tooling and Arrangement, Material Storage and Handling.

B6. ELECTRICAL

Description: The preparation of cable, straps, and other items for installation and manufacture of components such as panels, switchboards and consoles. Testing of purchased components.

Points Evaluated: Extent of work done by shipyard and subcontractors.

67. RIGGING

Description: Fabrication of rigging for installation on ships and fabrication and maintenance of crane cables, slings and similar equipment used by yard workmen.

Points Evaluated: Extent of Shipyard Work, Equipment.

W. MAINTENANCE (MEASURE OF THE MAINTENANCE SYSTEM)

Description: The system and material support methods for maintaining plant equipment and tools used in production, including cranes.

Points Evaluated: Maintenance Philosophy, Maintenance Material.

B9. GARAGE

Description: Service and maintenance of transportation equipment.

Points Evaluated: Extent of work done by shipyard and/or subcontractors.

B10. GENERAL STORAGE

Description: Storage facilities and practices for small items such as fasteners, welding rod, gasket material.

Points Evaluated: Storage Density, Order Picking, Material Handling.

B11. AUXILIARY STORAGE

Description: Storage facilities and practices for large, heavy equipment such as pumps, generators and large valves.

Points Evaluated: Storage Density, Order Picking and Locating, Material Handling.

C OTHER PRE-ERECTION ACTIVITIES

c1. MODULE BUILDING

Description: This refers to assemblies of auxiliary equipment, pipe and valves in self-supporting modules ready to be placed aboard ship. This could include pipe assemblies such as reducing stations, heat exchangers and pumps, etc.

Points Evaluated: Extent of Module Building, When Module Installed, Testing.

C2 OUTFIT PARTS MARSHALLING

Description: The collection into one kit or area all the material, technical information and tools needed to construct a module or discrete piece of work.

Points Evaluated: When Marshalling Takes Place, Scope of Marshaling.

C3. PRE-ERECTION OUTFITTING

Description: This is concerned with the degree of outfitting done on steel work prior to erection on the ways or building dock.

Points Evaluated: Percent of Pre-Erection Outfitting of Total Outfit, Scope of Pre-Erection Outfitting in % (approx.).

C4. BLOCKASSEMBLY

Description: This refers to the construction of natural sections or blocks of the ship that may weigh up to 1000 tons. Is generally done for VLCC ships in Japan and Europe.

Points Evaluated: Degree of Block Assembly, Welding Practices, Fairing, Dimensional Control.

C5 . UNIT AND BLOCK STORAGE

Description: Title self-explanatory. Reason for requiring storage may be because block construction sequence may not necessarily coincide with ship construction sequence.

Points Evaluated: Location of Storage Area, Designation of Storage Areas, Handling.

D SHIP CONSTRUCTION AND INSTALLATION

D1. SHIP CONSTRUCTION

Description: This is concerned with the basic ship construction process, use of sliding ways, docks -- portion of work done in shops vs. berths and speed of construction.

Points Evaluated: Building Positions, Output per B.P./year, Crane Capacity, Building Process, No. of Building Positions Used.

D2. ERECTION AND FAIRING

Description: This pertains to erection and fairing on ways or in building tools.

Points Evaluated: Unit Size, Hanging Time, Dimensional Control, Alignment Methods, Fairing.

D3. WELDING

Description: Pertains to welding on ways, in docks or outfitting pier.

Points Evaluated: Welding Process, Welder Mobility, Joint Preparation.

i)4. ON BOARD SERVICES

Description: This pertains to services such as electricity, water, compressed air, other gases--on board ship on ways, in building dock and outfitting pier.

Points Evaluated: Extent of Services, Services Configuration, Housekeeping.

D5. STAGING AND ACCESS

Description: Staging and access on ways, building dock and outfitting pier.

Points Evaluated: Staging Methods, Access, Housekeeping.

D6. PIPEWORK (INSTALLATION)

Description: The installation of pipe, valves and other pipework aboard ship.

Points Evaluated: Source of Information, Timing and Place of Installation.

D7. ENGINE ROOM MACHINERY (INSTALLATION)

Description: The installation of main and auxiliary machinery in units, blocks or the ship after erection.

Points Evaluated: Timing and place of installation.

D8. HULL ENGINEERING (INSTALLATION)

Description: Installation of deck machinery (e.g., steering gear, winches, windlasses) in units, blocks, or the ship after erection.

Points Evaluated: Timing and place of Installation, Trades.

D9. SHEET METALWORK (INSTALLATION)

Description: Installation of sheet metal products (e.g., ducts, galley equip., vents) in units, blocks or the ship after erection.

Points Evaluated: Source of Information, Timing and place of installation, Trades.

D10. WOODWORK (INSTALLATION)

Descrption:: Installation of woodproducts (e. g., panels furniture, blocks, shores) in units, blocks or the ship after erection.

Points Evaluated: Source of Information, Timing and place of work.

D1l. ELECTRICAL (INSTALLATION)

Description: Installation of electrical and electronics equipment, and cable in units, blocks and on the ship after erection.

Points Evaluated: Equipment Installation, Cable Installation, Testing.

D12. PAINTING

Description: Priming and painting ship structure and outfit including plates and stiffeners from stockyard.

Points Evaluated: Method of Painting, Preparation, Timing.

D13. TESTING AND COMMMISSIONING

Description: Final test of mechanical and electrical sys tern.

Points Evaluated: Organization, Records.

D14. AFTER LAUNCH

Description: Status of outfitting at launch.

Points Evaluated: Outfitting Status.

E LAYOUT AND MATERIALS HANDLING

El. LAYOUT AND MATERIAL FLO!i

Description: The adequacy of the plant layout and material flow to support efficient production.

Points Evaluated: Site Constraints, Material Flow.

E2 . MATERIALS HANDLING

Description: This is an overview of the entire shipyard material handling system which has to a large extent, been covered in most of the other elements.

Points Evaluated: Equipment, Storage Area, Coordination.

F ENVIRONMENT AND AMENITIES

F1. GENERAL ENVIRONMENTAL PROTECTION

Description: Concerns environmental protection provided men and material in terms of weather, temperature, housekeeping.

Points Evaluated: Housekeeping, Meather Protection, General Working Conditions, Material Storage.

F2. LIGHTING AND HEATING

Description: Adequacy of lighting and heating.

Points Evaluated: Lighting, Temperature.

F3. NOISE, VENTILATION, FUME EXTRACTION

Description: Adequacy of noise control, ventilation and fume extraction.

Points Evaluated: Noise, Ventilation and Fume Extraction. ‘

F4. CANTEEN FACILITIES

Description: Adequacy of food service and vending facilities.

Points Evaluated: Level of Service.

F5. WASHROOMS/W.C.’s/LOCKERS

Description: Adequacy of washrooms, W.C.’s and Lockers.

Points Evaluated: Lockers, W.C.’s, Showers, Changing Facilities.

F6. OTHER AMENITIES

Descrption: Adequacy of recreational and cultural facilities.

Points Evaluated: Recreational (mainly sports) Facilities, Cultural Facilities, Sponsorship.

G DESIGN, DRAFTING, PRODUCTION ENGINEERING AND LOFTING

G1. SHIP DESIGN

Description: Ship design to support contract actions and to provide a basis for production drawings. Typically includes: general arrangement, lines, shell plates, midship section, system drawings, and specifications.

Points Evaluated: Shipyard role, Methods, Data, Research.

G2. STEELWORK DRAWING PRESENTATION

Description: Production drawings necessary for Classification Society approval, steel procurement and for enabling shipyard workers to build the ship.

Points Evaluated: Production Orientation, Drawing Methods.

G3. OUTFIT DRAWING PRESENTATION

Description: Production drawings necessary for fabricating (local manufacture items), locating and installing pipe, wire, ducts, hull fitting, machinery, joiner work, insulation, etc.

Points Evaluated: Production Orientation.

G4. STEELWORK CODING SYSTEM

Description: A system (symbols) for numbering plates and stiffeners so they can be identified throughout the production process.

Points Evaluated: Type of symbols, Standardization, Coverage.

G5. PARTS LISTING PROCEDURE

Description: The procedure used for listing parts for steelwork and outfit as an aid to purchase and production.

Points Evaluated: Extent, Method.

G6. PRODUCTION ENGINEERING

Description: Production Engineering includes plant layout, equipment design, methods, standard practices and design for production. Deals with how the ship is to be built.

Points Evaluated: Organization, Scope, Products.

G7. DESIGN FOR PRODUCTION

Description: Ensuring that ship designs and drawings support efficient manufacturing, erection and installation processes and take advantage of the capabilities of shipyard equipment.

Points Evaluated: Relationships, Production Orientation.

G8. DIMENSIONAL AND QUALITY CONTROL

Description: Ensuring the control of dimensions and quality so that specifications will be met and efficiency of production will be enhanced.

Points Evaluated: Organization, Scope.

G9. LOFTING NETHODS

Description: Translating information on drawings to a form useful to production in performing steel work and outfitting.

Points Evaluated: Methods, Coding Sheets, Responsibility.

H ORGANIZATION AND OPERATING SYSTEMS

H1. ORGANIZATION OF WORK

Description: The amount of flexibility allowed management in the assignment of work to the separate trades.

Points Evaluated: Trade restraints, area supervision work station organization.

H2. CONTRACT SCHEDULING

Description: The master schedule which sets the planning boundries and constraints for the construction projects includes schedules for preproduction, drawing office and classification society activities plus key date and erection schedules.

Points Evaluated: Degree of Refinement, Resource Planning.

H3. STEELMORK PRODUCTION SCHEDULING

Description: Schedules for the preparation, cutting, fabrication and assembly of plates and stiffeners into sub-assemblies, units and blocks.

Points Evaluated: Degree of refinement, schedule coordination with demand schedule.

H4. OUTFIT PRODUCTION\ SCHEDULING

Description: Schedules for the production (manufacturing) of outfit items.

Points Evaluated: Degree of refinement, coordination with demand schedule.

H5. OUTFIT INSTALLATION SCHEDULING

Description: Schedules providing the desired time periods and sequences for installation of outfit items, both yard manufactured and purchased.

Points Evaluated: Degree of refinement, coordination with demand schedule.

H6. SHIP CONSTRUCTION SCHEDULING

Description: Schedules for the assembly of units, blocks and other steelwork on the ways or building dock.

Points Evaluated: Degree of refinement, coordination with demand schedule.

H7. STEELWORK PRODUCTION CONTROL

Description: This control function concerns the ordering, sequencing and execution of work. It includes material control and provision of services.

Points Evaluated: Work Control, Material Control.

H8. OUTFIT PRODUCTION CONTROL

Description: This control function concerns the ordering, sequencing and execution of work. It includes material control and provision of services.

Points Evaluated: Work control, Material Control.

H9. OUTFIT INSTALLATION CONTROL

Description: This control function concerns the ordering, sequencing and execution of work. It includes material control and provision of services.

Points Evaluated: Work Control, Material Control.

H10. SHIP CONSTRUCTION CONTROL

Description: This control function concerns the ordering, sequencing and execution of work. It Includes material control and provision of services.

Points Evaluated: Work Control, Material Control.

H1l. STORES CONTROL

Description: The management of material receipt, movement, location, stock control and issue -- central storage facilities only.

Points Evaluated: Methods, Records, Integration.

H12. PERFORMANCE AND EFFICIENCY CALCULATIONS

Description: Systems for measuring performance (accomplishment) and efficiency in terms of progress and cost to date and work station operation.

points Evaluated: Measures Used.

H13. COMPUTER APPLICATIOIIS

Description: The extent to which computer capabilities are utilized over a range of shipyard operations.

Points Evaluated: Uses.

H14. PURCHASING

Description: Purchase of material from outside sources.

Points Evaluated: Organization, Pre-delivery Inspection, Progressing and Expediting.

APPENDIX B

SAMPLE LEVEL CRITERIA FOR SHIPBUILDING TECHNOLOGY

Level

Al Plate Stockyard and Treatment

Plates stored in racks or on the ground and handled by mobile cranes. Informal material control. Men on the ground in the body of the stockyard. Either no steel treatment facilities or only manual shotblasting and priming.

Horizontal storage of material generally neatly stacked. Overhead cranage using slings or vacuum
lift. Men on the ground in the body of the stock- 2
yard. Informal recording system for location of material. Non-integrated treatment line.

Well laid out and drained stockyard. Preplanned locations for plates. Magnet handling by over-
head cranes. No men in the body of the stock- 3
yard. Integrated, automated treatment line with high quality primer applicatiOn.

Fully automated stockyard, computer controlled
cranes for input and withdrawal. Automated 4
treatment line.

B1 Pipework

Mainly hot bending and fabrication facilities with very low level of mechanization. No tube
handling equipment. All tube stored on the 1
ground. Standard AC m.m.a. for fillet welding flanges. Gas brazing.

Manually operated individual. machinery with no specialized handling equipment. Tube stored in
shipyard manufactured tube racks. Serviced by 2
mobile or overhead crane. Manual TIG sets. AC/DC m. m. a. butt welding

Automatic individual machinery, positional jigs and specialized handling equipment. Established
product lines. High density tube storage arrange- 3
ments with specialized handling devices. Manual TIG sets. Semi-automatic equipment for ferrous and non-ferrous. Pipe rotator with fixed auto head.

B1 (Cont'd)

		Level
	NC pipe production lines incorporating conveyors and tube suppiy Cassettes all controlled by punch tape or card. Fully automatic pro: grammed orbital TIG welder. Pipe rotator with fixed automatic welding head. Semi-automatic equipment for ferrous and non-ferrous.	4
C3	Pre-Erection Outfitting	
	No pre-outfitting of steelwork done prior to erection of unit	1
	partial pre-outfitting of adjacent steelwork units and such work as painting of marked areas, pipe supports, cable trays, etc.	2
	Substantial pre-outfitting of units and blocks prior to erection including pump rooms) engine room, control room, etc.	3
	Complete pre-outfitting of units and blocks with systems finished and tested before erection.	4
D5	Staging and Access	
	Principally a lug and bracket system, employing wooden scaffolding planks. Gangways used for access to the upper deck."	1
	Principally patent staging and permanent scaffolding arrangements augmented by lug and bracket system. Limited use of wire suspended platforms and hydraulic arm vehicles.	2
	Good range of access equipment including patented staging, hydraulic scissor lift platforms, wire suspended platforms and hydraulic arm vehicles. Deck access by lift.	3
	Extensive range of access equipment. Preplanned staging arrangements involving prestaging of units before erection. Purpose-built jig for propeller, rudder and rudder stock installation including *all* scaffolding requirements. Lifts and escalators used to provide access to various levels of the ship during construction and fitting out.	

E2	Materials Handling	Level
	Small parts manhandled. Extensive use of cranes for handling between production stages. Handling activities generally uncoordinated. Ill-defined storage areas.	1
	Some use of pallets and fork lift vehicles for handling and storage of small parts. Less reliance on cranage for handling between production stages. Units generally handled by crane and stored within reach of cranes. Some definition of storage areas. Non self-elevating transporters.	2
	Extensive palletized system for steel and outfit materials, components and sub-assemblies. Self-elevating, self-propelled transporters used with stools and trestles for movement of large steel and outfit components and assemblies. Well defined storage areas throughout shipyard. Coordinated handling activities.	3
	As 3. Emphasis on conveyors and special purpose handling and manipulating equipment in all areas.	4
F1	**General Environmental Protection**	
	Buildings generally untidy and in a run-down state, offering poor working conditions. Little or no attention given to protection from weather to labor force working outside.	1
	Mainly old buildings with below average working conditions. Limited attention given to protection from weather for labor force working outside. Poor housekeeping in some *areas.*	2
	Above average working environment with well maintained buildings. Good housekeeping in most areas. Attention given to protection from weather for most of the outside working force.	3
	Good working environment in all buildings. Considerable attention paid to environmental protection or all shipbuilding functions carried out under cover. Good housekeeping throughout the shipyard.	4

G7 Design for Production	Level
Little or no involvement of production department at the design stage. Few or .no natural blocks. Many obvious features in ship design which clearly demonstrate that design is not production orientated.	1
Little or no involvement of production department in detailed design of structure and outfit. Unit breakdown decided by yard manager and designer alone. Natural blocks generally confined to midship portion. Some production orientated design features.	2
Good coordination between production, planning and technical departments. Continuous involvement by production in detailed design considerations. Account taken of ease of access for equipment and staging during erection of ship. Increasing design for production in outfit installation.	3
Structural arrangements and block breakdowns developed to give rapid and economic erection, fairing and welding. Full advantage taken of characteristics of all manufacturing facilities to give best overall production efficiency. Excellent coordination between production, planning and technical departments.	4

H2 Contract Scheduling	
Cardinal or key date program only. Key dates established on the basis of lead or *lag* times only - no detailed quantification of resources.	1
Time based network analysis or development of key date program into bar chart form allowing simple handling of resources.	2
Resource analyzed networks or similar.	3
Integrated computer system enabling variations in strategy to be assessed.	4

APPENDIX C

EXAMPLES OF CORRECTED SURVEY NOTES

Note:
This Appendix is a true copy of the survey botes as they were completed by the MEL surveyor and, then, corrected by the shipyards. The shipyards[1] notations have been encircled and darkened to increase their legibility.

A-1 Plate Stockyard and Treatment

Shipya

Date_

DESCRIP: The storage, handling, treatment and cmtrol of plate from receipt to delivery to the cutting area.

CONS IDEATIONS:	STEEL	OTHER	Note Index
Method of storage:		Aluminum	(1)
on the ground	X		
Vertical		Al	
Horizontal	x	X	
Neatly stacked	X	X	
Pre-planned Iocation s	X	X	
Handling:			
Mobile cranes {Track}		X	
Overhead cranes			
Slings/vacuum lift			
Magnet	X		
Conveyers & Selector Gr	X		
Other (grappers, hooks)		X	
Treatment:			
None at this state		X	
Shot blasting	X		
Priming	None	None	(3)
Integrated (automated) (Leveler, preheat, blasting, priming, delivery)	No	No	
Manning:			
Men in stockyard	3	4	
Highly automated	No	No	
Control:			
Informal selection			
Informal location control			
Pre-planned locations	x	X	(2)
Computerized			

(1) Stored on heavy wood timbers 10"x12".

(2) Well organized manual system of recording storage location and means of retrieval.

(3) We were told that priming was not done at this stage because no one primer could accomodate the large variety of required paint systems.

(4) Aluminum storage not as well kept as steel storage.

Al.- Plate Stockyard and Treatment

Ship:

Date.

Working Area (SQ. FT.) — Plate only
261,000
Total 1,000,000 (Total area - plates - shapes - [illegible])

Open ✕ Roof only ______ Bldg. ______ Age 10 yrs.

Note Index

Environment	Visual Impression Poor	Fair	Good
Lighting			
Ventilation			
Heating - AC	/	/	?
Housekeeping — Noise		✕/	✕/✕
Layout - Malt. flow	/	/	✕ /✕

? NW

(4)

Employment (at time of survey)

Total 3 yard - [illegible]

Supervisors ______

Equipment

	No.	Visual Impression Poor	Fair	Good	Age
Crane.	1			✕	10 yr
Blasting	1			✕	"
Painting					
Selection Line	1			✕	"

? NW

Steel Processing Rate 6000 T per Mo

10 000 T/Mo (design)
4700 (Act Max)

Stock Levels: (weeks supply)		Steel	Other
	Max	9mo	9mo
	Ave.	3/4 mo	3/4/mo

Material Handled

Steel, common	50
Steel, special	40
Aluminum	10
Other	____

A1 Plate Stockyard & Treatment

The plate stockyard is well laid out with plates stored in planned locations and by position in stack. Handing is by magnet cranes, rail cars and horizontal conveyors. Steel stockyard manned by three people the aluminum stock yard by four. Steel plates automatically shotblast but not primed.

Aluminum plates stored vertically and horizontal. in pre planned locations served by ~~[illegible]~~ truck crane with hand clamps.

Rail? NW

B-1 Pipework

Shipyard-

Date

		Note Index
DESCRIP: Fabrication (manufacture) of pipe and fittings (e.g., bending, Flanging, priming, etc.) prior to installation.		

CONSIDERATIONS:

		Note Index
Storage:		
Ground	SOME	VARIOUS LOCATIONS
Simple racks	MOST	
High density with specialized handling devices	SOME	(MAGNETIC CRANE)
Welding:		
Manual metal arc AC - AC/DC	80%	
Manual inert gas	20%	
Pipe rotator with fixed auto head	✓	
Semi - automatic equipment	✓	2 TIG
Fully automatic programed equipment	NO	
Bending & Fabricating:		
Hot bending, little mechanization	NEGLIG	ABOVE 6" DIA.
Manually operated machinery	✓	
Automatic machinery, positional jigs, specialized handling equipment	NO	
N.C. machinery in production line setup	NO	

B-1 Pipework

Shipyard
Date____

Working Area (SQ. FT.) ① ②

Σ 50,800 Total 24,600+7,000 IN BLDG 805 + 7200 IN COPPER SHOP + 12,000# PIPE INSULATION

Note Index

Open______Roof only______Bldg. ✓ Age 30-60

Environment	Visual Impression (PIPE SHOP) Poor	Fair	Good	805	COPPER SHOP
Lighting			✓	GOOD	FAIR-GOOD
Ventilation/NOISE			✓/✓	GOOD/GOOD	GOOD (MECH)/
Heating - AC	/	/	✓/0	GOOD/0	GOOD/0
Housekeeping			✓	GOOD	GOOD
Layout - Matl. flow	/	/	✓/✓ ③	GOOD/GOOD	GOOD/GOOD

Employment (at time of survey)

Total 17

Supervisors 5

Equipment	No.	Visual Impression Poor	Fair	Good	Age	
Cranes 15T	1			✓	35	1-10T
Tools						
Shop Equipment						
1/2" TK. SHEAR	1			✓	10	CUTTING + THREADING
18" BAND SAW	1			✓	10	
TIG WELDERS	2			✓	2	

① BUILDING IS A PIPE WAREHOUSE, 7,000 S.F. OF WHICH IS USED TO CUT PIPE. PIPE FOR A SYSTEM IS PLACED IN KITS.

② A SEPARATE SHOP FOR ALL COPPER + BRASS WORK. IT HAS FACILITIES TO FORM LARGE PIPE FROM SHEETS.

③ ZONED FOR PIPE HANGERS, PIPE ASSEMBLIES, RADIOGRAPHY, HEATING COILS, ETC.

B1 Pipework

Shop machinery is manually operated and work is handled by various ordinary cranes. Most piping is stored in simple racks, although there is some high density storage. Most welds are made manually, but there are three semi automatic welding units in use. Non ferrous piping is fabricated in a different shop by usual ~~manual~~ methods

C-3 Pre-Erection Outfitting

Shipyard

Date ____

DESCRIP: This is concerned with the degree of outfitting done on steel work prior to erection on the ways or building dock.

Note Index

CONSIDERATIONS:

Percent of Pre-Erection Outfitting of Total Outfit:

Ship Type	DWT	
Tanker		
Cargo ship		
EFG 7		~~[illegible]~~ 2-5%

Scope of Pre-Erection Outfitting in % (approx.)

	Flat Units	Curved Units	3D Unit	Super-struct.	Block	Note Index
Int. Paint					X	
Ex. Paint					X	Not finish coat.
Scaffolding Supports						
Pipe Support						
Cable ways					10%	
Piping					X	in lower bottoms very little elsewhere.
Aux. Machinery						
Grating					Some	
Ladders						
Vent ducks				X	X	
Joiner work				X	X	Dias for insulation.
Access				X	X	
Airports						
[illegible]				X	X	some

C-3 Pre-Erection Outfitting

The ~~amount~~ of pre outfitting prior to erection seems to be minimal at this time ~~includes~~ pipe in innerbottoms, some vent ductwork, foundations, painting, supports for cable ways. The yard reports an intent to accomplish pre-outfitting to the maximum possible extent, consistent with availability of material and the capacity of existing lifts.
The current FFG (NAVY) construction run is in fact experiencing an increasing % of pre-erection outfitting in furtherance of the yard's stated goals.

D-5 Staging and Access

Shipyard.

Date ___

DESCRIP: Staging and access on ways, building dock and outfitting pier.

Note Index

CONSIDERATIONS :

% etc.

Staging Methods:
- Lug & bracket &wood planks ___
- Patent staging (pipe) ___
- Wire suspended platforms ___
- Hydraulic arm vehicles ___
- Hydraulic scissor lift platfoms ___
- preplanned stage before erection ___
- Purpose - built jigs for
  - propeller ___
  - rudder ___
  - rudde stack ___
- Other: Staging towers ___

Access :
- Gangways ___
- Stairtowers ___
- Elevators 4
- Escallators ___

Housekeeping:	Poor	Fair	Good
On scaffolding			___
Access			

D5 Staging & Access.

The greater majority of the staging consisted of patented pipe staging with a liberal amount of staging towers, particularly in the tanker cargo tanks. There was a limited amount of leg and bracket in certain confined areas. There was an erection stage for the stern areas. In fabricating the cargo tanks of the LNG ships, the contractor employed a special staging that permitted transferring the support from one set of legs to another.

Lead

C-6 Materials Handling

Shipyar

Date___

Note Index

DESCRIP: This is an overview of the entire shipyard material handling system which have to-a large extent, been covered in most of the other elements.

CONSIDERATIONS :

Equipment: % Approx.

Operation	Small parts movement	Handling between production stages	Steel	Outfit materials	Components	Sub-assemb s	Lge. steel & outfit components & sub-assem.	
Manhandled	✓			✓				
Cranes	✓	✓	✓	✓		✓	✓	
Fork lift & pallets	✓	✓	✓	✓	✓			
Non self-elevating supporters	✓	✓	✓		✓	✓	✓	
Self elevating, self propel. transporters		✓				✓	✓	
Conveyors		✓	✓			✓		
Special purpose handl. & manipulating equipment								
Straddle crane	✓		✓					

Including rail cars.

Storage Area:
- 111 defined (space available) ___
- Some definition of storage areas ✓
- Well defined storage throughout yard ___

Coordination:
- No coordination of work vs material handling equipment capability or availability ___
- Some coordination ✓
- Well thcught out ___

C6 Material Handling -

The yard appears to rely on fork lift and straddle carriers for the bulk of their smaller lifts and transports. Straddle carriers are used almost exclusively for the movement of stiffeners and shapes for the fab shops. Plates are moved by automatic conveyors from the treatment plants to the fab shops. The arrangement of the older yard was laid out around a railroad transportation system which is still in very active use. There are excellent crane facilities throughout the shops and the yard. There are two heavy lift cranes - one over the basin used for the construction of aircraft carriers has a capacity of 300 T and the other over the large commercial basin has a capacity of 900 T. There is at least one ~~300~~ T self propelled transporter for the movement of subassemblies. The storage of material in the open yard is in several areas. Warehousing is extensive and some very modern. All storage of material is computerized

E-2 General Environmental Protection Ship

Date

DESCRIP: Concerns environment protection provided men and material in terms of weather, temperature, housekeeping.

CONSIDERATIONS:

		Note Index
Housekeeping:		
Poor generally		
Poor in some areas	✓	
Good in most areas	✓	
Good throughout		
Weather Protection:		
Very little for outside force	✓	1.
Some for outside force		
Most outside fores protected		
Considerable attention or all work under cover		
General Working Conditions:		
Poor		
Fair		
Good	✓	2.
Material Storage:		
Envimnment virtually ignored.		
Some material protected	✓	3.
Most material protected (cover or inside)		

Notes:
(1) Note buildings designed for purpose including speciall materials handling.
(2) Note general age of bui I dings.
(3) Emphasize housekeeping.

1. But very seldom has protection been necessary (until 1977-1978 when longer periods of inclement weather have been encountered (which is the exception in San Diego))
2. Conditions involving temperatures, lighting, fumes and dust are generally good. Noisy areas are mostly those areas which are not practical to suppress in a shipyard work environment (sledging/hammering/chipping/grinding/sawing, etc.) where ear protection is all that is mostly done. Housekeeping is fair to good in most areas.

E-2 GENERAL ENVIRONMENTAL PROTECTION

The working environment is generally above average in the areas of temperatures, lighting, fumes and dust. Buildings are mostly older buildings but are not in bad condition. There is no weather protection for the outside work force. Housekeeping is "fair" to "good"

3. All material which requires protection is stored in Covered areas. Note the warehousing required has caused the leasing of three warehouses off-site from the main shipyard

G-7 Design for Production

Shipyard.

Date ____

DESCRIP: Ensuring that ship designs and drawings support efficient manufacturing, erection and installation processes and take advantage of the capabilities of shipyard equipment.

CONSIDERATIONS:

		Note Index
Relationships:		
Production departmnt not involved in ~~design~~		
Production department not involed in detail design of structure and outfit		
Production department continuously involved		
~~Gho~~d coordination between production, technical and planning departments		
Excellent coordination between production technical and planning departments	✓	1.
Manifestations:		
Design clearly not production oriented		
Some orientationfor production		
Few or no natural blocks		
Natural blocks confined to midships		
Unit breakdown not influenced by production department		
Access and staging considered		
Manufacturing capabilities considered	✓	2
Erection, welding and fairing considered		
Outfit installation designed for production	✓	3.

1. Four people from production planning stationed full time in engineering dept re current Navy contract.

2. Steel panel line was installed when current 3 ship Navy contract was awarded.

3. Assembly and module breakdown and erection sequence designed to permit most efficient machinery installations.
For third ship of current contract, a computer printout is being produced listing every item within a module, permitting complete and timely gathering of required materials and facilitating increasing pre-erection outfitting.

G-7 Design for Production

There is ~~good~~ coordination between production, planning and engineering departments and continuous involvement by production in detailed design considerations. Account is taken of ease of access for equipment and staging during erection of ship an increasing design effort for production in outfit installation is in evidence.

H-2 Contract Scheduling

Shipyard_

Date

Note Index

DESCRIP: The master schedule which sets the planning boundries and constraints for the construction project; includes schedules for preproduction, drawing office and classification society activities plus key date and erection schedules.

CONSIDERATIONS :

Degree of Refinement:		
Key date program only by Production Dept.		
Time bassd network analysis or development of key date bar charts	yes	①
Resource analyzed networks		
Computer system facilitating evaluation of alternatives		
Resource planning:		
None based on schedule		
Simple handling based on bar chart		
Substantially based on network analysis		
Resource alternative derived by computer	yes	②

① The initial schedules are preliminary event schedules which take into account resource requirements (manpower, facilities), long lead time materials, make or buy, design capability, potential bottlenecks. The depth is dependent on the possible problems anticipated. Networks are required by the Navy.

② Manpower requirements and availability for all shop sections, etc. are maintained in the computer, with regular printouts of backlog, etc. Demands of new projects are ~~[illegible]~~ reviewed with this data in hand and alternatives are considered (e.g., hire, transfer to another shop or plant, buy, reschedule)

H-2

The shipyard develops principal events schedules, expanded in areas as indicated, which cover all activities from beginning of design, material procurement, special facilities, production and test events, etc. Detailed manpower and facilities resources are examined against work in hand and projected. Alternatives are weighed. The manpower data are computerized and the schedule (principal events schedule) becomes the master schedule for all subsequent subordinate schedules which are all on the computer in the greatest detail.

APPENDIX D

UNITED STATES SHIPYARD

HISTORIES AND DESCRIPTIONS

BATH IRON WORKS CORP., BATH, MAINE

The yard started building ships in 1889 and developed in capability through World War I and II, chiefly as a builder of Navy Destroyers. In 1967, it was acquired as a subsidiary. of the predecessor of the Congoleum Corporation. It is currently constructtig and undertaking major overhauls of Naval ships, while simultaneously contracting to construct major commercial *cargo* ships and small tankers.

SHIPYARD CHARACTERISTICS

Site: The main yard is situated along the-bank of the Kennebec RiveR, a few miles from the Atlantic Ocean. It is about 40 miles from the city of Portland. The Hardings steel facility cuts and fabricates steel and is located 5 miles inland from the main yard.

Acreage: 92

Access: It is accessible to major highways and has rail facilities in both the main yard and Hardings Plant. There is no supporting industry in the vicinity and materials and equipment are purchased from other segments of the country. It is 40 miles to the Portland Airport.

Expansion Possible: Limited

Bath Iron Works

Facilities:

Docks :	l-Floating 413' x 85' (7600 T lift)
Berths:	1-548' x 92' 1-545 ' x 83' 1-519' x 83'
Piers :	2900 '

Maximum Ship Size: 700' x 130' (20,000 T Lt. Ship Wt.)

Is Site Fully Occupied by Supporting Facilities: Yes

YARD ACTIVITY

Type Work in Recent Years: Navy Destroyers and Frigates, Ro/Ro ships, container ships, small tankers and major Navy overhaul and conversion.

Traditional Clientele Providing Base Load: Mostly Naval with. some intermittent commercial (subsidized and private).

Recent Ship Completions 1973-1977: (over 1000 gross tons)

1973	2 Container ships
1974	2 Tankers
1975	3 Tankers
1976	3 Ro/Ro ships
1977	1 Ro/Ro ship & 1 FFG

Labor Force: 4/78

Total Plant	- 4408	Ship Repair	- 949 (Navy)
Naval Const.	- 1490	Non-ship	- 137
Comm. Const.	- 1217		- 613

Bath Iron Works

Work in Progress: (as of 31 December 1977)

2 - Container ships
11 - Guided Missile Frigates

Type of Work Expecting in Future:

Commercial and Destroyers

Type of Work Yard Believed Best Suited:

Commercial 30,000T
Destroyers (New Construction and Overhaul).

GENERAL DYNAMICS CORPORATION-QUINCY SHIPBUILDING DIVISION
Quincy, Mass.

This yard was purchased from Bethlehem Steel in 1964. It is a highly diversified yard and has constructed both commercial and Naval (conventional and nuclear powered) ships over many years. It is not a repair yard.

SHIPYARD CHARACTERISTICS

Site: The yard is located in the outskirts. of Boston on the Fore River in Weymouth, Massachusetts. Access to Boston Harbor and the Atlantic Ocean is through a highway bridge that imposes beam restrictions. Associated with the main yard is a new spherical. LNG container facility near Charleston, South Carolina. Its capacities are in excess of present shipyard requirements.

Acreage: 187 (172 in use)

Access: It is accessible to major highways -and has rail facilities serving the yard. It is about 20 miles to Logan International Airport.

Expansion Possible: No

Facilities:

Docks :	2-867′ x 132′ 2-874′ x 132′ 1-950′ x 150′
Berths :	None
Piers :	4600 ′

Maximum Ship Size: 936′ x 143′ (no limit on ship weight)

Is Site Fully Occupied by Supporting Facilities: Yes

YARD ACTIVITY

Type Work in Recent Years: LNG ships, large barge carrying ships (SEABEES) and Naval Auxiliary ships.

Traditional Clientele Providing Base Load: Commercial and subsidized ships; however, is interested in entering Navy field again.

Recent Ship Completions 1973-1977 (over 1000 gross tons)

1973	1 Barge carrying ship (Seabee)
1974	0
1975	0
1976	0
1977	2 LNG ships

Labor Force: *(as* of June 1978)

Total Plant - 5791	Ship Repair - --
Naval Const. 64	staff - 199
Comm. Const.- 3429	- 2099

Work in Progress : (as of 31 December 1977)

8 LNG ships (125,000 cu. m.)

Type of Work Expecting in Future:

LNG Ships
DDG 47 (Navy)

Type of Work Yard Believes Best Suited:

LNG Ships and Complex Naval Vessels

GENERAL DYNAMICS CORPORAT1ON
Charleston, S.C. Facility
(LNG Sphere Manufacturing Facility)

The Charleston Facility was designed and constructed for the fabrication of specialized tanks (800T Aluminum Spheres) for installation in the Liquid Natural Gas (LNG) tankers built at the General Dynamics, Quincy Shipbuilding Division. In late 1974, due to the inability of the sub-contractor to supply the spheres in support of the ongoing LNG tanker building program, General Dynamics took over and completed the Charleston facility. Fabrication of the first sphere commenced in July 1975. Subsequently, on December 7, 1976, two years and one day after take over of the Charleston site, the first completed sphere arrived via barge at the Quincy, Mass. yard. The sphere manufacturing facility is very modern and is, at present, the only one of its kind in the world. The spheres can be used for floating or land based storage as well as for transport of LNG.

FACILITY CHARACTERISTICS

Site: The facility is located northeast of Charleston, S.C. on the Cooper River, 22 miles from the Atlantic Ocean. The site is approximately 900 miles distant by sea from the Quincy Shipyard.

Acreage: 87

Access: It is accessible to major highways and is served by rail facilities. It has direct access to the Atlantic Ocean, via the Cooper River. It is close to the Charleston Municipal Airport.

Expansion Possible: There is a considerable amount of open ground plus 3.2 acres of swamp.

Facilities:	Piers: Barge Slip:	110' x 220'
	Plate Yard:	100' x 700', 1-20T crane
	Crane Support Structure (Sphere Assembly)	570' Length x 375' Width X 215' Ht.
	Fabrication Shop:	
	Low Bay	100' x 300'
	High Bay	100' x 800'
	Trans-lift Units(Completed Sphere Transporter) 3 ea. 335T Cap.)	

Is Site Fully Occupied by Support Facilities: No

FACILITY ACTIVITY

Type Work in Recent Years: Solely devoted to the fabrication and delivery of aluminum LNG spheres. The first sphere was delivered in December 1976. The facility is capable of the simultaneous construction of six spheres (approximately eighteen weeks per sphere) with delivery rate of one sphere every two and one-half weeks.

Traditional Clientele Providing Base Load: Serves the Quincy Shipbuilding Division, General Dynamics Corp.

Work in Progress: Aluminum LNG Tanks.

Type of Work Expecting in Future: Continued sphere production in support of the construction of LNG tank ships. Excess capacity could support outside LNG construction. Possible additional sphere production in support of floating liquification and storage facilities.

Type of Work Yard Believes Best Suited: As above.

SEATRAIN SHIPBUILDING CORP. BROOKLYN, N. Y.

In 1969, Seatxain Shipbuilding Corporation, a subsidiary of Seatrain Lines, Inc., leased the principal facilities of the former Brooklyn Navy Yard. It was established to build 225,000 DWT Tankers on an assembly line basis, with special emphasis on large steel modules. It has very modern steel handling, fabrication and assembly facilities.

SHIPYARD CHARACTERISTICS

Site: The yard is located in metropolitan New York and is part of the former Brooklyn Navy Yard situated on the East River in New York. It has direct access to the Atlantic Ocean.

Acreage: 80

Access : It is accessible to major highways and is served by rail facilities. It is close to Kennedy International and La Guardia Airports. There is some supporting industry in the New York-New Jersey Metropolitan area.

Expansion Possible: Yes

Facilities:

Docks :	2-1093′ X 150′ (60,000 T Wt.) 1- 758′ X 113′ (40,000 TWt.)
Berths:	None
Piers:	4600 ′

Maximum Ship Size: 1094′ x 143′

Is Site Fully occupied by Supporting Facilities: No

Type Work in Recent Years: Large tankers (225,000 DWT), large barges and major ship rebuilding.

Traditional Clientele Providing Base Load: Commercial work only, both subsidized and private.

Recent Ship Completions 1973-1978 (over 1000 *gross* tons)

1973	1 Tanker	(225,000 DWT)	
1974	1 Tanker	(225,000 DWT)	
1975	2 Barges	(10,481 DWT)	
1976*	6 Barges	(10,481 DWT)	* I Icebreaker Barge (8,787 DWT)
1977	1 Tanker	(225,000 DWT)	
	1 Barge	(6,570 DWT)	
1978	1 Tanker	(225,000 DWT)	
	1 Barge	(483′ x76′ X 36′)	
	11 Barge	(3,458 DWT)	

Labor Force: as of April 1978

Total Plant -	2096	Ship Repair - -	
Naval Const. -		staff -	
Comm . Const. -	1334		- 762

Work in Progress

2 Tug-Barge Container Units Ro/Ro (6,450 DWT ea.)
1 Ro/Ro Barge
1 Chemical Carrier Conversion (34,000 DWT)

Type of Work Expecting in Future:

Tankers	Oil Barges
Ro/Ro Barges	Repairs of Ships & Barges
Container Barges/Ships	Navy/MrAd/MSC Ships

Type of Work Yard Believes Best Suited:

Same as above.
Where heavy steel construction is required.

SUN SHIPBUILDING AND DRY DOCK CO.
Foot of Morton Avenue
Chester, pA 19013

Sun Ship, an independent subsidiary of Sun Company, has been in operation over 60 years and has constructed over 600 vessels in that period. Essentially a commercial yard, the shipyard does actively pursue and has experience in Naval work. Sun constructs a wide range of general cargo, bulk cargo, and specialty vessels. In addition, Sun has complete facilities for ship repair, ship conversion, and industrial products including a heavy machine shop.

Sun Ship offers a full scope of engineering services including the design of new vessels, ship conversion and product development for industrial, aerospace and hydrospace applications.

SHIPYARD CHARACTERISTICS

Site: The yard, 15 miles south of Center Philadelphia along the Delaware River, has direct access to the Atlantic Ocean and to the Chesapeake Bay *via* the Chesapeake-Delaware Canal. The channel off the yard is maintained to 45 feet at mean low water.

Acreage: 180

Access: Sun has access to major highways, is 6 miles. from the Philadelphia International Airport, and *has* direct access to both the Conrail and Reading Railways.

Expansion Possible: Yes.

Facilities:

New Construction Capacity

4 end launching ways:

# of way	Dimensions	Max. Ship Size	Cranes Serving Way
#1 & #2 Presently Inactive	Length 670′ Width 80′	LOA - 635′ Beam- 85′ Weight- 8000T	Bridge - 20T 2-15T
#6 &#8	Length 740- 10″ Width 139′	LOA - 745′ Beam- 132′	Gantry 45 - 50T@ 65′ @ 65′

Building Platform:

One 700 ft. square building slab capable of building ships to 400,000 DWT. Slab has two sections for simultaneous construction of two halves of one large ship or two smaller vessels. It is serviced by five (5) gantry cranes (2-250T capacity, 3-75T capacicy)

Note:	Maximum size of 400,000 dwt vessel:	LOA 1,100 Ft. Beam 190 Ft.
	Maximum size of 2 smaller vessels: These vessels are 30,000 dwt each.	LOA 650 Ft. Beam 90 Ft.

Pier Capacity:

Ships' Berths No.	Length	Water Depth Inboard-Outboard	Cranes Serving Berths
1	600 Ft.	17 Ft. - 21 Ft.	
	600 Ft.	22 Ft. - 26 Ft.	2 Gantries 21T @ 55 Ft.
2	500 Ft.	21 Ft. - 22 Ft.	2 Gantries 21T @ 55 Ft.
3	960 Ft.	34 Ft. - 25 Ft.	2 Gantries 21T @ 55 Ft.
5	550 Ft.	24 Ft. - 24 Ft.	1 Gantry 21T @ 55ft.
6	1100 Ft.	30 Ft. - 30 Ft. (Outfitting Pier)	5 Gantries 3 - 75T)

Floating Dry Dock:

#4 floating dry dock is a two-section dry dock capable of accormmodating vessels with widths of Up to 197 ft. and with its 700,000 ton lifting capacity, is capable of handling vessels up to 400,000 deadweight tons.

When used independently, each 350 ft. section is capable of lifting 35,000 tons. When used together, the two sections may. be spaced up to 20 ft. apart, giving #4 dry dock a 900 ft. LOA.

The dry dock is serviced by two 23.5-ton, and two 10-ton gantry cranes.

Supplemental Heavy Lift Equipment:

A wheeled, 212 ton capacity transporter capable of moving large sub-assemblies from the fabrication shops to the new construction sites.

The Sun 800 is a barge-mounted derrick with an 800-ton lifting capacity that may be moved to the outfitting pier, floating dry dock, or ship piers whenever additional heavy lift capacity is required.

Fabricating Shop:

120T capacity per eight hours and served in high bay by 5 bridge cranes (2 -75T, 2 - 30T, 1 - 20T) and in the low bay by 4 bridge cranes (1 - 20T, 1 - 15T, 2 - 10 T).

Support Shops:

In addition to the above, separate shops and facilities are maintained in the yard for specialty operations in conjunction with ship construction, repair and industrial production as follows:

Boiler Shop	Electric Shop
Pipe Shop	Carpenter Shop
Copper Shop	Burner Shop
Sheet Metal Shop	Blacksmith Shop

Additional Sun Ship Facilities and Capabilities:

In addition to the shipways and outfitting piers, Sun Ship has facilities to incorporate a wide variety of fabrication and machining operations. Included in these operations are:

(1) Plate preparation equipment which will cut metal up co 10" thicknesses.
(2) Rolling equipment which will roll 1 /2" plate to a minimum of 38" O.D.
(3) 2,000 Ton hydraulic press which accepts plates up to 4" thickness.
(4) Two car bottom stress relieving furnaces up to 18' x 18' x 80' with a maximum temperature of l,400°F.
(5) Vertical segmented stress relieving furnace 26' in diameter with a height of 60' and maximum temperature of l,300°F.
(6) Vertical boring mills which have up to 22' diameter swing and 55 ton capacity.
(7) Horizontal boring mills which can bore to 48' depth.

(8) pressure testing facilities Up to 60,000 PSI.
(9) Balancing machines sensitive to 1 oz. /inch which can simulate speeds up to 10,000 RPM.
(10) Torque testing facilities up to 29 million in. /lb. with 25' diameter shaft maximum.

Maximum Ship Size: 110O' x 195' in two halves)

Is Site Fully Occupied by Supporting Facilities: No

YARD ACTIVITY

Type Work in Recent Years: Cargo ships, *Ro/Ro vessels,* medium sized tankers, container ships and LNG carriers, also ship repair and industrial manufacturing.

Traditional Clientele Providing Base Loads: Commercial clients primarily, some Naval work.

Recent Ship Completion 1973-1977:

1973 3 cargo ships
1974 1 cargo ship
1975 3 cargo ships, 1 tanker (124, 000 DWT)
1976 2 tankers
1977 1 cargo ship

Labor Force: *Total Plant less staff equals yard crafts (as of September 1978).

Total Plant -	3,500 to 5,000	Ship Repair	
Navy Const. -	*	Non-ship	
Comm. Const.-	*	Staff	350: to 500

Work in ?rogress: (as of 31 December 1977)

2 LNG (130,000 cu. m.)
2 Tankers (118, 000 DWT)

Type of Work Expecting in Future:

3 Ro/Ro Container Ships

Type of Work Yard Believes Best Suited:

Any type of vessel over 500 feet long requiring sophisticated, complex engineering design.

BETHLEHEM-SPARROWS POINT SHIPYARD, SPARROWS POINT, MARYLAND

This yard is the last of the several shipbuilding yards formerly operated by Bethlehem Steel. The remaining yards concentrate in repair, barge and special vehicle construction. The yard was originally established in 1891 and became part of the Bethlehem organization in 1916. It is primarily a shipbuilding yard.

SHIPYARD CHARACTERISTICS

Site: The yard is situated at the head of Chesapeake Bay, about 200 miles from the Atlantic Ocean. It is adjacent to a Bethlehem Steel Plant and near the city of Baltimore. It has a frontage of about 3500' on the Bay and about 2400' deep.

Acreage: 200 (142 used, the balance below water)

Access: It is accessible to major highway systems with direct connection to 3 major railroads. It is 15 miles from International Airport and is in an industrial complex.

Expansion Possible: Feasible

Facilities:

Docks:	1-1200' x 200' (50,000 T. Lt ship Wt)
Berths	2-769' X 110' (15,000 T) 2-625' x 90' (11,000 T) now used as platens
Piers:	3870'

Maximum Ship Size: 1200′ x 192′ (50,000 T. Wt.)

Is Site Fully Occupied by Supporting Facilities: Yes

YARD ACTIVITY

Type Work in Recent Years: Mostly commercial - tankers up to 265,000 DWT, Container ships, floating Navy dock. It does not undertake repair work.

Traditional Clientele Providing Base Load: Tanker and cargo ship owners, both private and subsidized construction.

Recent Ship Completions: 1973-1977 (over **1000 gross** tons)

1973 1 Container, 3 Tankers
1974 1 Container, 2 Tankers
1975 1 VLCC Tanker
1976 2 VLCC Tankers
1977 1 VLCC Tanker
1978 1 VLCC Tanker, .1 ULCC Bow

Labor Force: 4478

Total Plant	- 3246	Ship Repair	
Naval Const.	- 214	Non-Ship	*163*
Comm.Const.	- 1755	Staff	*1114*

Work in Progress: (as of 31 December 1977)

2 - Container Ships
1 - VLCC
2 - ULCC Bow Sections (NNSB&D)

Type of Work Expecting in Future:

Ocean Going Barges

Typee of Work Yard Believes Best Suited:

Tankers, bulk carriers, container ships, **Naval** auxiliaries, structural work, pipe work and anything which would utilize available facilities

NEWPORT NEWS SHIPBUILDING AND DRYDOCK CO.
Newport News, Va.

This company, founded in 1886, is presently considered the largest shipbuilding complex in the world. In 1968, it became a subsidiary of TENNECO, INC. It is highly diversified and is the only yard capable of building and servicing the full range of nuclear-powered ships-carriers, cruisers, submarines. It constructs both commercial and Navy ships, and also undertakes considerable repair work, both naval and merchant.

SHIPYARD CHARACTERISTICS

Site: It is located at the mouth of the James River and has direct access to the Chesapeake Bay and thence the Atlantic Ocean. It has recently completed in 1977 a large new North Yard with the capability of building vessels over 400,000 DWT. The yard extends two miles along the river. The yard has a large foundry, forge, machine shops, etc. and is at present the most self-sufficient yard in the U.S.

Acreage: 475 (302 used)

Access: It is accessible to major highways and has complete rail facilities to the yard. It is reasonably close to both the Norfolk and the Newport News Airports. There is increasing development of supporting industries but much of the required materials and equipment are shipped from outside the area.

Expansion Possible:

Yes - 150 acres underway - can do more if needed.

Facilities:

Docks: 1-960′ x 128′ (Graving)
1-1100′ x 140′ (Graving)
1-1600′ x 250′ (Graving, 900 T crane, in new yard)
1-650′ x 92′ (Graving-repair drydock)
1-862′ x 118′ (Graving-repair drydock)
1-458′ x 72′ (Graving-repair drydock)

Berths: 1-447′ x 90′
1-649′ x 90′
1-637′ x 61′
2-882′ x 128′

Piers: 12,400′

Maximum Size Ship: 1600′ X 240′ (700,000 DWT)

Is Site Fully Occupied by Supporting Facilities:

YARD ACTIVITY

Type of Work in Recent Years: Highly diversified with nuclear aircraft carriers and submarines, cruisers, large tankers, LNG carriers and commercial cargo ships. It has a large major ship repair business and also undertakes considerable non-ship work, primarily goods and services for the nuclear power generating industry.

Traditional Clientele Providing Base Load: Navy and commercial operators, as well as industrial.

Expansion Possible:

Yes - 150 acres underway can do more, if needed.

Facilities:

Docks:	1-960' x 128' (Graving)
	1-1100' x 140' (Graving)
	1-1600' x 250' (Graving, 900 T crane, in new yard)
	1-650' x 92' (Graving-repair drydock)
	1-862' x 118' (Graving-repair drydock)
	1-458' x 72' (Graving-repair drydock)
Berths:	1-447' x 90'
	1-649' x 90'
	1-637' x 61'
	2-882' x 128'
Piers:	12,400'

Maximum Size Ship: 1600' x 240' (700,000 DWT)

Is Site Fully Occupied by Supporting Facilities: No

Type of Work in Recent Years: Highly diversified with nuclear aircraft carriers and submarines, cruisers, guided missile cruisers, large tankers, LNG carriers and commercial cargo ships. It has a large major ship repair business and also undertakes considerable non-ship work, primarily goods and services for nuclear power generating industry.

Traditional Clientele Providing Base Load: Navy and commercial operators, as well as industrial.

Recent Ship Completions: 1973-1977 (over 1000 gross tons)

1973	
1974	1 Guided Missile Frigate
1975	1 Nuclear Submarine, 1 Guided Missile Frigate, 1 Aircraft Carrier
1976	2 Submarines, 1 Guided Missile Frigate
1977	1 Aircraft Carrier 1 Guided Missile Frigate 2 Nuclear Submarines

Labor Force: 4/78

Total Plant - 24995	Repair Work - Navy 769, Comm. 1072
Naval Const. - 12579	Non-ship - 595
Comm. Const. - 5310	- 4670

Work in Progress: (as of 31 December 1977)

3 LNG Carriers (125,000 cu. m.)
3 Tankers (390,000 DWT)
1 Aircraft Carrier
2 Guided Missile Frigate
11 Nuclear Submarines

Type of Work Expecting in Future:

Aircraft carriers, cruisers, submarines, commercial shiP, industrial products.

INGALLS SHIPBUILDING DIVISION, LITTON SYSTEMS
Pascagoula, Mississippi

This shipyard, acquired by Litton Industries in 1961, originally started in 1938 as Ingalls Shipbuilding Co. The older of the two yards is referred to as the East Bank Yard, and the new facility completed in 1970 is known as the West Bank Yard. It is a diversified yard,building both commercial and Naval ships. At one time, the East Bank was used for the construction of nuclear submarines, and at present it is performing major nuclear submarine overhauls.

SHIPYARD CHARACTERISTICS- (EAST BANK)

Site: This is the original shipbuilding facility located in Pascagoula, Mississippi, near the Gulf of Mexico. It is "located about 40 miles from Mobile, Alabama, a large port, and about 120 miles from New Orleans, *also* a major port.

Acreaze: 178 (151 used)

Access: It is served by major highways and has suitable rail facilities. The closest major airport is in Mobile about 40 miles distance. There is no supporting industry in the vicinity and it procures its materials and equipment throughout the country.

Expansion Possible: Not applicable, based upon reduced activity in yard

Facilities:

Docks : 1-460' x 73' x 35' (Graving)

Building Ways: 1-690' X 85'
4-650' x 90'
1-550' x 80' } Inactive, but still in good condition. Cranes have been moved to West Bank but can be returned if needed.

Piers: 3100'

Maximum size Ship: 650' X 90' (18,000 T. Wt.)

Is Site Fully Occupied by Supporting Facilities:

The steel fabricating shop and platens are being dismantled. There is a 5 year plan to phase out the remaining shops.

SHIPYARD CHARACTERISTICS-(WEST BANK)

Site: This yard is directly across the Singing River from the East Bank Yard and adjacent to Pascagoula. This yard was developed for modular shipbuilding concepts, with special emphasis on multiple Naval ship construction. It is almost square in shape, being built on filled land. It faces water on three sides.

Acreage: 611 (use 400)

Access: (See East Bank)

Expansion Possible: Yes

Facilities :

Docks : 1-640′ x 177′ (38,000 T. lift) launch pontoon

Berths: launch max. ship size of 800′ x 173′ - five bays producing 225′ long x 6000 T modules, estimated equivalent of six conventional inclined ways.

Piers: 4400 ′

Maximum Size Ship: 800′ x 173′

Is Site Fully Occupied by Supporting Facilities: Yes

YARD ACTIVITY (EAST AND WEST BANK)

Type Work in Recent Years: Mostly Naval, however, previously heavily involved in *commercial* construction. Constructs destroyers, amphibious attack ships, Navy auxiliaries, merchant cargo ships, rankers and (formerly) nuclear submarines.

Traditional Clientele Providing Base Load: Navy and commercial operators.

Recent Ship Completion: (over 1000 gross tons)

1973	6	Cargo ships
1974	1	Cargo ship
1975		Destroyer
1976	4	Destroyers, 1 LHA
1977	6	Destroyers, 1 LHA

Labor Force: 4/78

Total Plant -	21618	Ship Repair - N	2089
Navy Constr.-	16619	Non-Ship -	
Comm. Const.-	0	Staff	2910

Work in Progress: (as of Dec. 31, 1977)

19 Destroyers
4 Destroyers (foreign)
3 LHA's

Type of Work Expecting in Future:

Navy

Type of Work Yard Believes Best Suited:

Navy

AVONDALE SHIPYARDS, INC. , NEW ORLEANS, LOUISIANA

This yard *was* established in 1938 and developed during World War II. In 1959, the capital stock was purchased by Bayou Shipyards, a subsidiary of Ogden Corporation. In addition to building ships, the yard's various divisions repair ships; fabricate *steel;* manufacture propellers and ship's equipment; build offshore drilling structures, tugs, supply boats and barges; make ferrous and non-ferrous castings; and warehouse steel for sale. Avondale employs about 8000 personnel and does about $450 million of business in 1978 dollars.

SHIPYARD CHARACTERISTICS

Site: It is situated on the banks of the Mississippi River, almost opposite New Orleans, about 100 miles up river from the Gulf of Mexico. It is a long, narrow yard, about 5000 feet long, built on the river levee. The confirmation of the yard has led to the development of the movement of large sections of ships, permitting flexibility in the size of vessels and numbers of vessels that can be concurrently constructed. Launching is by side launching or the lateral movement of the ship into a floating drydock.

Acreage: 218

Access: It is accessible to major highways and has rail facilities to the yard. There is deep water at the docks for loading and unloading by barge and ship. There is some supporting industry in the vicinity. However, most of the materials and equipment are purchased from other segments of the country. It is about 15 miles to the New Orleans International Airport.

Expansion Possible: With the present facility, the labor force can be increased to 7200 for the full utilization of the Facility. With the addition of a gantry crane spanning the two construction positions of the upper yard, ships up to 210 feet in beam and about 350,000 DWT can be built. The floating dock used for launching can be lengthened by welding additional 90-foot-long sections utilizing cofferdams around the joints. Other **fabrication areas** and facilities can be increased to suit.

Facilities:

Docks	1-900′ x 260′ (81,000 T. lift - floating dock used in launching, and available for repair and conversion 40 weeks of the year)
	1-224′ x 80′ (used for repair)
Berths:	1-600′ x 80′ (2 ships simultaneously - side launched)
	1-1050′ x 174′ (3 ships simultaneously - side launched)
	1-1200′ x 126′ (5 ships simultaneously - side launched
Piers:	Approximately 3600′

Maximum Ship Size: 1050' x 174' - 260,000 DWT

Is Site Fully Occupied by Support Facilities: **Yes**

YARD ACTIVITY

Type Work in Recent Years: Highly diversified; break bulk cargo ships, containerships, RO/RO vessels, LASH vessels, LNG ships, tankers up to 164,000 DWT, Destroyers, Coast Guard Cutters, drill rigs, dredges, barges, repair, conversion and industrial.

Traditional Clientele Providing Base Load: Private, subsidized, and military.

Recent Ship Completions 1973-1977: (over 1000 gross tons)

1973	6	LASH ships, 4 Destroyers, 3 Drill Rigs
1974	5	LASH ships, 3 Destroyers, 3 Drill figs, 1 Major Conv.
1975		LASH ship, 4 Drill Rigs, 3 Ocean Barges, 1 Major Conv
1976	1	Drill Rigs, 2 Major Conversions
1977	2	Major Cargo Ship Conversions, 1 Tanker

Labor Force: (as of 1 July 1978)

Total Plant - 5971	Ship Repair - 1578
Naval Const. - 270	Non-ship - ---
Comm. Const. - 3673	- 450

Work in Progress: (as of July 19, 1978)

5 - Navy Oilers (AO'S)
3 - LNG Ships (125,000 cu. m.)
2 - LASH Vessels
4 - Tankers (164, 000 DWT)
4 - Supply Vessels
Oceangoing Barge
4 - Drill Platforms

LEVINGSTON SHIPBUILDING CO-
Orange, Texas

This yard was founded in 1933. Gulfport Shipbuilding, in Port Arthur, *Texas,* was purchesed in 1970 to supplement Livingston's construction and repair facilities. In 1975, it became a wholly owned subsidiary of Ashland Oil Inc. Since the inception of offshore oil drilling, most of the company's work has been related to this industry.

SHIPYARD CHARACTERISTICS

Site: It is situated on the Sabine River approximately 30 miles inland from the Gulf of Mexico. It is about 25 . miles to Beaumont and 120 miles to Houston. The main construction yard, which is being expanded and modernized, is located on a island, connected by a bridge to the office, and some of the older facilities.

Acreage: 99 (80 used)

Access: It is adjacent to major highways and is served by rail. It is served by the Houston International Airport and Beaumont Airport (30 miles). There is some industry within the vicinity of the yard.

Expansion Possible: Yard has approximately 20 acres of un- developed land area and more that 3000 feet of undeveloped

waterfront.

Facilities:

Docks :	1-350' x 84'	(Floating capacity)	6000 LT
	1-388' x 126'	(Floating capacity)	11,000 LT
	1-220' x 72'	(Floating capacity)	3,200 LT

Berths: 1-1150' x 100'

Piers: 2400'

Marine Railway: 1.225' x 45' (1000 LT capacity)

Maximum Ship Size:

700' x 100' (10,000 T Lt. ship)

Is Site Fully Occupied by Supporting Facilities: No

YARD ACTIVITY

Type Work in Recent Years: Drill rigs, drilling ships, supply tanker barges.

Traditional Clientele Providing Load: Private, serving petro-chemical industry and off-shore drilling industry.

Recent ship Completions 1973-1977: (over 1000 gross tons)

1973 3 Semi-submersible Rigs, 1 Pipe-laying Barge, 1 Homer Barge, 1 Tug

1974 1 Pipe-Bury Barge, 1 Drillship
1975 1 Jack-up Rig, 1 Semi-submersible Rig, 1 Drillship
1976 1 Jack-up Rig, 1 Semi-submersible Rig
1977 2 Jack-up Rigs, 1 Drillship
1978 1 Tanker, 1 Drillship, 3 Inland Drilling Barges

Labor Force: (as of 31 July 1978)

Total Plant -	2154	Ship Repair	- 345
Navy Const. -		Non-ship	- 88
Comm.Const. -	2179		- 442

Work in Progress: (as of 31 July 1978)

1 Jack-up Rig
1 Drill Ship
3 Inland Drill Barges
1 10,000 DWT Tanker

Type of Work Expecting in Future: Immediate prospects include five DWT bulk carriers, two jack-ups, two offshore launch barges. Expect a mix of conventional ships/offshore vessels.

Type of Work Yard Believes Best Suited: All types of commercial vessel.

NATIONAL STEEL AND SHIPBUILDING CO. (NASSCO)
San Diego, California

This yard was started in 1945, building fishing vessels and in 1957 entered the large ship market. In 1962, it was taken over jointly by Morrison-Knudsen Company, Inc. and Kaiser Industries Corporation. The yard is the largest shipbuilding complex on the West Coast and is also one of the major shipbuilders in the U.S.

SHIPYARD CHARACTERISTICS

Site: It is located in San Diego, California and has direct access to the Pacific Ocean.

Acreage: 145

Access: It is accessible to major highways and has rail facilities into the yard. It is about five miles to the San Diego airport. There is only limited supporting industry, hence most of the material and equipment is shipped into the yard by rail, truck or water.

Expansion Possible: No

Facilities:

Docks :	1-1000′ X 179′	(Graving)
	1-397′ X 52′	(Floating)
	1-687′ x 90′	(Graving-leased from Port District)
Berths:	2-905′ x 115′	
	1-675′ x 96′	
Piers :	7075′	

Maximum Size Ship: 980′ X 170′ (33,000 T. wt.)

Is Site Fully Occupied by Supportings Facilities: No. Sub-contracting is used for joiner, decking and insulation work.

YARD ACTIVITY

Type Work in Recent Years: Highly diversified yard; builds large naval auxiliaries, cargo ships, bulk carriers and tankers (up to 188,000 DWT)..

Traditional Clientele Providing Base Load: Navy and cormnercial ship owners.

Recent Ship Completions 1973 - 1977 (over 600 gross tons

1973 1 Tanker (38,000 DWT), 1 Bulk/Oil (80,000 DWT)
1974 1 Tanker (89,000 DWT), 1 Bulk/Oil (80,000 DWT)
2 Tankers (38,000 DWT)
1975 2 Tankers (89, 000 DWT) ,2 Tankers (38, 000DWT)
1976 5 Tankers (89, 000 DWT) 1 Tanker (38, 000 DWT)
1977 4 Tankers (89, 000 DWT) ,1 Tanker (38, 000DWT)
1978 1 Tanker (89 ,000)DWT) , 1 Tanker (188,500 DWT)

Labor Force: (as of 1 April 1978)

Total Plant - 5957	Ship Repair-Navy 415, Comm. 25
Naval Const.- 2286	Non-ship - 194
Comm. Const - 1282	Staff - 1755

Work in Progress: *(as* of 3 August 1978)

3 188,500 DWT Tankers
2 Navy Destroyer Tenders

Type of Work Expecting in Future:

1 Navy Tender - included in budget and probable

award expected.. Bidding 4-5 containerships to A.P.L.

Type of Work Yard Believes Best Suited:

Yard has followed the mix of Navy non-combatants and various commercial ships as best fitting their facilities.

TODD SHIPYARDS CORP. - LOS ANGELES DIVISION
San Pedro, California

Todd is engaged in ship and barge construction, ship conversion and ship repair at seven facilities spread among the three coasts of the United States. Only two of these yards construct as well as repair ships, namely Los Angeles and Seattle Divisions. The Los Angeles Division was formerly the Los Angeles Shipbuilding and Drydock Company and was purchased by Todd in 1947.

SHIPYARD CHARACTERISTICS

Site: The yard is located on San Pedro Bay with *easy* access to the Pacific Ocean. It is part of the Los Angeles Metropolitan Area. It has water on two sides and is rectangular in shape.

Acreage: 90 (66.12 land, balance water)

Access: It has ready access to major highways and is about 10 miles to Los Angeles Airport. It has rail facilities serving the yard. The area has some supporting industry services. How*ever,* much of the material and equipment comes from more remote areas.

Expansion Possible: Yes, as required, inland.

Facilities:

Docks: 1-563' x 85' (10,500 T lift) Floating
1-665' x 85' (17,000 T lift) Floating

Berths: 1-527' x 95' (20,000 T Wt.)
1-647' x 87' (8,000 T Wt.)

Piers: 4400'

Maximum Ship Size: 600' X 93' (20,000 TWt.)

Is Site Fully Occupied by Supporting Facilities: No, room exists for facilities as needed, except piers and ways.

YARD ACTIVITY

Type Work in Recent Years: Commercial and Navy shipbuilding and repairs; cargo ships, small tankers, large ship conversions guided missile frigates and destroyer escorts. Mostly Naval work at present.

Traditional Clientele Providing Base Load: Commercial owners and Navy.

Recent Ship Completions 1973-1977: (over 100 gross tons)

1973	0	
1974	1	Tanker (25,000 DWT)
1975	3	Tankers (25,000 Dwt)
1976	2	Tankers (35,000 DWT)
1977	2	Tankers (35,000 DWT)
1977	1	Ammonia/LPG Carrier Forebody, (32,000 M^3 - 480' X 90' X 52)

Labor Force: (as of August 1, 1978)

Total Plant - 2800	Ship Repair - 768
Navy Const. - 1434	Non-ship - 10
Comm.Const. - 0	Staff,Other - 369
	Vacation,Sick-leave,Absences- 219

Work in Progress:

9 Guided Missile Frigates (FFG), 2 Navy Overhauls (LSD and AD)

Type of Work Eepecting in Future:

Same as recent ship completions.

Type of Work Yard Believes Best Suited:

Same as recent ship completions.

TODD SHIPYARDS CORP. - SEATTLE DIVISION - SEATTLE , WASHINGTON

The original yard was founded in 1898 and in 1916 was acquired by William H. Todd Company, the predecessor of Todd Shipyards. It is one of two Todd yards undertaking both construction and repair of commercial and naval ships. (See Todd Shipyards Corp. - Los Angeles Division for additional information).

SHIPYARD CHARACTERISTICS

Site: This yard is located in the northwest corner of Harbor Island in Elliot Bay, about 10 minutes from downtown Seattle. It is a compact facility, square in s-nape with two sides facing water.

Acreage: 47

Access: It is readily accessible to major highways and is served by rail facilities. The yard is about 15 miles from the Seattle International Airport. There is some supporting industry in the vicinity, but most of the material and equipment comes from other parts of the country.

Expansion Possible: Roughly five acres of leased property available on long-term basis.

Facilities:

Docks:	1-650′ x 85′ (18,000 T lift) Floating 1-420′ x 63′ (5,700 T lift) Floating 1-550′ x 92′ (16,000 T lift) Floating
Berths:	2-450′ X 65′ (4,500 T St.) 1-550′ X 130′(5,500 T Wt.)
Piers:	4850′

Maximum Ship Size:

550′ X 96′ (5,500 T Lt. Wt.)

Is Site Fully Occupied by Supporting Facilities: Yes

YARD ACTIVITY

Type Work in Recent Years: Construction of destroyer escorts and frigates, ferries, barges and tugs. Repair of naval and commercial ships and industrial work for aerospace and hydro-electric industries.

Traditional Clientele Providing Base Load: Commercial operators, Navy and shore-based industry.

Recent Ship Completions: 1973-1977 (over 1000 Gross Tons)

1973 2 440′ Ferries - Washington State
1974 6 Tug/Supply Vessels (British Regisry 1250 Gr. Tons)
1975 2 500′ Phosphate Barges
1976 4 Deck Cargo Barges (250′)

Labor Force:

Total Plant	- 2,400	Ship Repair	- 500 Navy 300 Commercial
Naval Const.	- 1,200	Non-ship	- 100
Comm. Const.	0	Staff	- 300

Work in Progress:

8 guided missile frigates (including 3 for Australia)
2 F.F.'s Base Line Overhauls
1 LSD Major Overhaul
Miscellaneous Vessel Repairs

Type of Work Expecting in Future:

FFG Construction
F.F. Overhauls

Type of Work Yard Believes Best Suited:

FFG Construction
F.F. Baseline Overhauls

LOCKHEED SHIPBUILDING AND CONSTRUCTION CO.
Seattle, Washington

This 87 year old company was formerly the Puget Sound Bridge and Dredging Co. It was acquired by Lockheed in 1959 and changed to its present name in 1965. It has built a wide variety of naval and commercial ships and is also engaged in repair work.

SHIPYARD CHARACTERISTICS (Plant #l)

Site: This yard is located in Seattle on the southern perimeter of Puget Sound's Elliott Bay. The yard is divided into two plants; the older one being Plant #1 and the newer across the West Water-Way. Plant #1 is limited in size which prompted the construction of Plant #2.

Acreage: 16.6 owned and 6.6 leased.

Access: It is located in the city and is served by major high-ways and rail. It is about 20 miles from the Seattle International Airport. There is some supporting industry in the vicinity, but much of the equipment and material is shipped from outside the state.

Expansion Possible: Not in Plant #1.

Facilities:

Docks: None

Berths: 1-650′ X 95′
1-666′ x 93′

Piers: 1700 ′

Maximum Size Ship: 650′ X 90′ (11,500 T Lt. Wt.)

Is Site Fully Occupied by Supporting Facilities: Yes

SHIPYARD CHARACTERISTICS (Plant #2)

Site: (see Plant #1)

Acreage: 30.5 owned and 25.5 leased.

Access: (see Plant #1)

Expansion Possible: Yes

Facilities:

Docks : 1-472′ x 46′ (Floating)
1-530′ x 80′ (Floating)
1-600′ x 96′ (Floating)

Berths : 1-700 ′ x 100′ (10,000 T Wt.)

Piers : 2700′

Maximum Size Ship: 700′ x 100′ (10,000 T Wt.)

Is Site Fully Occupied by Supporting Facilities: No

YARD ACTIVITY (PLANTS #1 and #2)

Type of Work in Recent Years: Naval and commercial construction and repair; destroyers, large Navy auxiliaries, Ro/Ro ships, bulk carrier, large ferries and icebreakers.

Traditional Clientele Providing Base Load: Navy, private owners, Coast Guard and states.

Recent Ship Completion: (over 1000 gross ton)

1973	1	bulk carrier
1974	1	large Alaskan Ferry
1975	0	
1976	1	Icebreaker
1977	1	Icebreaker

Labor Force:

Total Plant	- 2858	Ship Repair	- 344
Navy Const.	- 2191	Non-ship	- 102
Comm.Const.	0	Staff	- 221

Work in Progress: (as of 31 December 1977)

3 Submarine Tenders

Type of Work Expecting in Future:

Navy

Type of Work Yard Believes Best Suited:

Navy

APPENDIX E

DESCRIPTIONS OF COMPARABLE FOREIGN SHIPYARDS

Note:
Shipyard names omitted to preserve confidentiality of shipyard technology level data contained in the body of the report.

SHIPYARD A

Activities

Best suited to vessels with high steelwork content, e.g. tankers, bulk carriers.

Maximum Ship Size

Concrete pad 244 x 51.8 m (300,000 dwt in two parts)

Principal Facilities

Two Berths - 268 X 40 m (for up to 150,000 dwt)
One Concrete Pad - 244 x 51.8 m served by 225 ton goliath crane

Well equipped steelshops and extensive outfit quays

Site area is 95 acres

Workforce Total 3,900

Recent Work

1973 - 1977	1	32,300	dwt bulk carrier
	2	264,000	dwt tanker
	1	25,187	dwt tanker
	2	75,390	dwt bulk carrier
	1	258,000	dwt tanker
	2	24,000	dwt cargo

present Work

1 - 258.000 dwt tanker
1 - Emergency Support Vessel

Comments

Yard reconstructed late 1950's early 1960's. Further redevelopment 1969 - 1972 included panel line and building pad with goliath crane.

SHIPYARD B

Activities

Construction of cargo vessels, oil tankers, bulk carriers, products tankers and ship repair.

Maximum Ship Size

1,000,000 dwt

Principal Facilities

1 - building dock - “556 x 93 m
1 2 - 840 ton goliaths with 140 m span straddle dock and adjacent block assembly area
4 - 60 ton cantilever (travelling) cranes are positioned round the dock
4 - building berths

Site area is 250 acres

Workforce Total - 6,000

Recent Work

1973 - 1977 - 3 - 269,000 dwt tankers
6 - 119,000 dwt bulk carriers
6 3 - 315,000 dwt tankers
1 - 333,000 dwt tanker

Present Work

1 - 37,500 dwt LPG
2 - 66,000 dwt products
2 - Car/passenger ferry (7,850 GT)
2 - 117,850 bulk carriers

Comments

All work is concentrated in one building dock. The yard has recently completed a ten year development plan and now has a very extensive modern facilities.

SHIPYARD C.

Activities

All types and sizes of vessels including tankers, bulk carriers, sopnisticated cargo vessels, naval auxilary vessels and naval vessels.

Medium Size

150,000 dwt

Principal Facilities

TWO or three building berths served by medium capactiy cranage. Steelshops developed generally within existing building, for high output of series ships. Sophisticated and effective manually based operating systems.

Site area is 50 acres

Workforce Total - 2,600

Recent Work

High rate of Production of various types of vessels. Delivering Up to twelve vessels per year.

Current work

Simple and complex commercial and naval vessels.

Comments

Yards in this model would include:

IHI - Tokyo
Mitsui - Tomano
Hitachi - Innoshima
NKK - Shimizu

yards are typically medium sized and have been gradually developed within their site constraints over the last fifteen years.

SHIPYARD D

Activities

Flexible shipyard constructing medium to large commercial tankers and gas carriers, and also cargo liners.

Maximum Ship Size

360 X 60m (350,000 dwt)

principal Facilities

1 - Building dock 360 x 60 m served by goliath cranes of 660 and 500 tonnes and jib cranes up to 250 tonnes.
1 - Berth 228 x 39.3 m served by 120 tonne jib crane and others
1 - Berth 172 x 31 m served by 120 tonne jib crane and others

There are 1,300 m of fitting-out quay.

Area of yard is 90 acres

WorkForce Total - 5,900

Recent Work

1973 -1977
- 6 - cargo liners
- 4 - refrigerated cargo liners
- 4 - methane carriers (40,000, 75,000, 120,000 and 125,000 m^3)
- 5 - LPG (66,000 m^3)
  92,000 dwt tankers
- 5 240,000 dwt tankers
  328,000 dwt tankers
- 2 - 20,000 dwt RORO's

Present Work

3 - 72,000 m^3 LPG
1 - 20,000 dwt RORO
1- 47,600 dwt container
2 - 21,400 dwt RORO's

Comments

The yard was redeveloped in the late 1960's early 1970's and has specialized in sophisticated vessels, particularly gas carriers, but has also built other types of vessels including ULCC's.

SHIPYARD E

Activities

Builder of specialist commercial, naval auxiliary and naval vessels

Maximum Ship Size

211 x 31.9 m (40,000 dwt)

Principal Facilities

Five berths

1 - 160 X 21.3 m (not usually used)
1 - 21 X 29.3 m
1 - 21X 31.9 m
2 - 122 x 15.3 m

Extensive outfit quay facilities

Site area is 35 acres

Workforce Total - 2,500

Recent Work

1973 - 1977 - 3 - 25,550 dwt products tankers
3 - submarines ('0' class)
1 - fleet tanker
1 - drill ship

Present Work

1 - fleet tanker (7,200 dwt)
1 - drill ship
1 - submarine

Comments

Yard improvements have been gradually undertaken over the past twenty years.

SHIPYARD F

Activities

Large vessels with a high steelwork content such as VLCC's and bulk carriers.

Maximum Ship Size

600,000 tons dwt

Principal Facilities

Large dock(s) served by goliath cranes. Computer controlled steel handling systems. Highly automated steel production lines. Sophisticated computer based technical and operating systems. Typically a capital intensive operation with high output and productivity.

Site area 200 acres

Workforce Total - 2,000

Recent Work

VLCC and ULCC delivered at a rate of approximately six a year

Current Work

Tending to build a smaller and more sophisticated vessel in accordance with market demands.

Comments

Yards in this model would include:

IHI - Chita
Hittachi - Ariake
Sumintoma - Oppama
Mitsubishi - Koyagi

High technology greenfield yards completed in the 1970's.

SHIPYARD G

Activities

Principally designed for efficient production of VLCC's

Maximum Ship Size

415 x 90 m (700,000 dwt)

Principal Facilities

2 - docks 300 m x 45 m (220,000 dwt) served by 1 75 ton and 4 50 ton cranes
1 - dock 415 x 90 m served by 1,040 ton goliath (155 m span) goliath spans both dock and storage block erection area
2 - outfitting basins 500 x90 m and 300 x 45 m

Site area is 210 acres

Workforce Total - 5,700

Recent Work

1972 - 1977 - 6 - 225,000 dwt tankers
4 - 310,000 dwt tankers
6 - 335,000 dwt tankers
3 - 320,000 dwt tankers
1 - 69,000 dwt products tanker
1 - 39,000 dwt bulk carrier

Present Work

3 - 69,000 dwt Products tanker
1 - 39,000 dwt bulk carrier
6 - 26,000 dwt multi-purpose (container)

Comments

Greenfield yard in 1958. Continuously updated since then.

SHIPYARD H

Activities

Commercial and naval work undertaken. Best suited to large bulk carriers, tankers and similar ships of low to medium specialization, although wide range of experience exists.

Maximum Ship Size

352 x 52.8 m (berth 1 and 2 combined) approximately 300,000 tonnes dwt

Principal Facilities

Four berths:

No 1. - 292.0 x 42.0 m)
No.2 - 280.0 x 42. 0 m) Not at the same time
No.3 - 262.1 x 38.l m)
No.4 - 262.1 x 38.1 m) Not at the same time

Site area is 40 acres

Workforce Total - 3,600

Recent Work

1973 - 1977 - 2 - 256,600 dwt tankers
1 - 15,460 dwt cargo
1 - 261,00 dwt tanker.

Present Work

1 - Anti-sub cruiser

Comments

Steel and outfit shops extensively redeveloped in the early 180 ton berth crane added mid 1970’s.

SHIPYARD J

Activities

Construction of large commercial ships

Maximum Ship Size

470 x 68 m

Principal Facilities

One building platfom 470 x 68 m served by a 750 ton goliath crane 130 m span, spanning both the building platform and the adjacent preassembly platfom. The preassembly platform is also served by a 240 ton goliath. An in-line continuation of the building platfom is a 415 x 68 m fitting out dock. There is also a 320 x 45 m dock (mainly used for fitting out) and a building berth (rarely used at present).

Area of yard is 170 acres

Workforce Total - 6,500

Recent Work

1973 - 1977 - 12 - 275,000 dwt tankers
2 - 550,000 dwt tankers
1 - 220,000 dwt tanker
3 - 75,000 m^3 LNG
1 - 122,000 dwt tanker
2 - 19,600 dwt multi purpose

present Work

2 - 61,500 dwt LNG
1 - 47,600 dwt container
1 - 540,000 dwt tanker
1 - 25,480 dwt tanker
2 - 36,540 dwt LPG
1 - 3,000 dwt RORO

Comments

Major redevelopment in 1968 in which new dock and building platform were built. Also panel line introduced and block assembly area. Since the development, capacity has been primarily directed towards large tanker production.

SHIPYARD K

Activities

Best suited to series production of large cargo ships, sophisticated bulk carriers, and other medium specialization ships.

Maximum Ship Size

275 x 35 m (80,000 dwt)

Principal Facilities

3 berths:

275 x 35 m
214 x 26 m
229 x 30 m

Total area is 65 acres

Workforce Total - 3,900

Recent Work

1973 - 1977 - 17 - 26,100 dwt bulk carriers
6 - 22,650 dwt general cargo
4 - 23,800 dwt cargo
1 - suction hopper dredger

Present Work

4 - 16,500 dwt bulk carrier
9 - 4,000 dwt bulk carrier

Comments

Redevelopment in the 1970's have included new 80 ton berth cranes, new steelshop equipment and some rationalization of outfit shops.

SHIPYARD L

Activities

This yard is best suited to the series production of commercial vessels of low to medium specialization.

Maximum Ship Size

330 x 44 m (230,000 dwt)

Principal Facilities

TWO adjacent building docks 334 x 46 m extend 35 m into a two bay 'Block Shop'. Units weighing up to 300 tons are erected in these areas to form 'rings' of ships, which are progressively pushed out into the open dock until the ship is completed.

Site area is 250 acres

Workforce Total - 3,500

Recent Work

1974 - 1977 -	13 -	155,000 dwt tankers
	10 -	141,000 dwt tankers
	1 -	227,000 dwt tankers
	1 -	105,000 dwt OBO

Present Work

5 - 154,000 dwt tankers
4 - 44,300 dwt bulk carriers
4 - 14,800 dwt reefers

Comments

A greenfield yard built in the mid 1960's, operating with two parallel building docks into which ships are extruded after being constructed under cover. It is a capital intensive, highly productive shipyard.

SHIPYARD M

Activities

Commercial and naval shipbuilding and repair and involvement with specialist offshore craft and structures

Maximum Ship Size

31 x 5 m (235,000 dwt)

Principal Facilities

3 building berths:
1 graving dock (repair work only) 351 x 59 m
6 floating docks (repair work only) up to 320 x 52 m

Shipyard area 120 acres

Recent Work

1973 - 1977 - 2 - 145,000 dwt bulk carriers
1 - 138,700 dwt bulk carrier
2 - pipe laying ships
crane ship
3 - 27,000 grt container ships
1 - 35,000 grt container ships
18,500 grt container ships
4 - 3,200 grt RORO's
South American Destroyers

Present Work

1 - derrick pipe laying ship
1 - 250,000 dwt capacity floating dock
1 - crane ship (2,500 tonnes lift)
1 - 1,300 dwt cargo ships
1 - 3,200 dwt cargo ships
1 - offshore workshop

Comments

Old established medium sized yard. Some development of yard facilities in the early 1960's.

SHIPYARD N

Activities

Commercial and naval shipbuilding of medium to large size

Maximum Ship Size

300 x 42 m (140,000 tonnes dwt)

Principal Facilities

Four berths :

190 x 24.8 m
300 x 33.0 m
300 x 42.0 m
275 x 35.6 m

Site area is 100 acres

Workforce Total - 5,400

Recent Work

The yard has built a variety of vessels of commercial type, and also a medium size range destroyer.

1973- 1976 - 1 - LPG (19,764 dwt)
General Cargo (17,575 dwt)
1 - Bulk carrier (34,400 dwt)
1 - Ferry (9,000 GRT)
1 - Products (20,400 dwt)
1 - 31,750 dwt products tanker
1 - 33,500 dwt products tanker

present Work

2 - medium size destroyers
1 - 31,750 dwt products tanker
1 - 55,000 dwt products tanker

Comments

The yard is just finishing major redevelopment which was started in 1972. When complete, the yard will

have covered construction facilities on two berths where ships will be constructed from the stern and extruded onto the berths. Ships will be substantially completed prior to launching.

SHIPYARD P

Activities

Construction of tankers, bulk carriers and other low to medium specialization vessels.

Maximum Ship Size

264 x 44 m (120, 000 dwt)

Principal Facilities

1 - dock 264 x 44 m
    Semi tandem construction of 60,000 ton dwt ships

Site area is 45 acres

Workforce Total - 1,600

Recent Work

1973 - 1977 - 2 - fore ends for 112,000 dwt tankers (during yard redevelopment)
2 - 112,000 dwt tankers
2 - 28,450 dwt bulk carriers

Comments

New shipyard built around existing dock 1973 - 1976. Designed for high productivity of tankers and bulk carriers.

SHIPYARD R

Activities

Large vessels such as tankers and bulk carriers, sophisticated cargo vessels, LNG, LPG and some naval vessels.

Maximum Ship Size

30,000 tonnes dwt

Principal Facilities

Either building docks with goliath cranes or berths with high capacity jib cranes. Well developed mechanised steel production facilities. Sophisticated computer based technical and operating systems. High output and productivity.

Site are 100 acres

Workforce Total - 6,000

Recent Work

Over the last ten years this type of yard has delivered five to ten ships a year, generally of the tanker, bulk carrier and sophisticated cargo type.

Present Work

Concentrating on sophisticated cargo vessels such as container ships, LNG and LPG carriers and some naval work. Also offshore vessels and structures.

Comments

Yards in this model would include:

IHI - Kure
Kawasaki - Kobe
Mitsubishi - Kobe
Mitsubishi - Nagasaki

These are typically large shipyards in heavily industrialised areas which have been extensively redeveloped within existing site constraints. Company activities usually include ship repair, engine building and heavy engineering on the same or adjacent site.

SHIPYARD S

Activities

Designed for high throughput of tankers and other large high steelwork content ships.

Maximum Ship Size

One building dock 470 m x 75 m. Two goliath cranes with lift capacities of 1,600 tons and 800 tons span the dock.

Site area is 200 acres.

Workforce Total - 6,1OO

Recent Work

1973 - 1977 -	10	255,000 dwt tankers
	14	357,000 dwt tankers

present work

2 - 66,000 dwt LNG
3 - 10,000 dwt container/RORO
3 - 16,000 dwt bulk cement carriers
Submarines

Comments

Builders of tankers, LNG, LPG, bulk carriers, DO and OBO and submarines. Major improvements have been continually made over the last twenty years.

APPENDIX F

COMPARABLE FOREIGN

SHIPYARD SELECTION

SHEETS.

SELECTION OF COMPARABLE YARDS

Criterla	Bath	Yard N	Yard E	Yard C	Yard M
Work Experience					
Past 10 years	A,B,D	A,B,D	B,C,D	A,B,C,D	A,B,C
Current	B,D	B,D	B,C,D	A,B,C,D	A,B,D
Maximum Ship Length	700	1000	680	850	1020
Employment	3300	5400	2500	2600	5500
Size (Acres)	92	100	35	50	120
New or Redeveloped	L	M	L	L	L

Discussion

There are five foreign yards roughly comparable to Bath Iron Works. One yard which emphasizes steel throughput and which has less complex ship capability was dropped.

SELECTION OF COMPARABLE YARDS

Criteria	G.D. Quincy	Yard B	Yard R	Yard J	Yard S
Work Experience					
Past 10 years	B,C,	A,B,D	A,B,D	A,B	A,B,D
Current	B	A,B	B,D	A,B	A,B,D
Maximum Ship Length	936	1800	1000	1500	1320
Employment	6300	6000	6000	6500	6100
Size (Acres)	172	250	100	170	200
New or Redeveloped	M	M	M	M	M

Discussion

There are six foreign yards roughly comparable to G.D. Quincy. The selection of four was substantially based on construction of similar ships and on the general level of sophistication

SELECTION OF COMPARABLE YARDS

Criteria	Seatrain	Yard P	Yard L	Yard G	Yard R
Work Experience					
Past 10 years	A	A	A	A	A,B,D
Current	A	A	A,B	A,B	B,D
Maximum Ship Length	1094	860	1080	1360	1000
Employment	2100	1600	3500	5700	6000
Size (Acres)	80	45	250	210	100
New or Redeveloped	M	M	N	N	M

Discussion

There are seven foreign yards roughly comparable to Seatrain. The four selected for comparison have high steel throughput and generally specialize in tankers and bulkers.

SELECTION OF COMPARABLE YARDS

Criteria	Sun	Yard A	Yard R	Yard G	Yard D
Work Experience					
Past 10 years	A,B	A,B	A,B,D	A	A,B
Current	A,B	A,B	B,D	A,B	A,B
Maximum Ship Length	1100	1100	1000	1360	1170
Employment	3000	3900	6000	5700	5900
Size (Acres)	160	95	100	210	90
New or Redeveloped	M	M	M	N	M

Discussion

There are eight foreign yards roughly comparable to Sun. The sample was reduced by eliminating yards emphasizing series production of less complicated ships and a relatively small yard producing specialized ships.

SELECTION OF COMPARABLE YARDS

Criteria	Beth. Sp.	Yard H	Yard P	Yard R	Yard G
Work Experience					
Past 10 years	A	A,D	A	A,B,D	A
Current	A,B,C	D	A	B,D	A,B
Maximum Ship Length	1200	1150	860	1000	1360
Employment	3200	3600	1600	6000	5700
Size (Acres)	142	40	45	100	210
New or Redeveloped	M	M	M	M	N

Discussion

There are seven foreign yards roughly comparable to Bethlehem, Sparrows Point. Two of the yards were eliminated-on-the basis that they generally construct-more sophisticated ships and one on the basis that it has a substantially higher steel throughput.

CTION OF COMPARABLE YARDS

Criteria	Newport N	Yard B	Yard F	Yard S	Yard J
Work Experience					
Past 10 years	A,B,D	A,B,D	A	A,B,D	A,B
Current	A,B,D	A,B	A,B	A,B,D	A,B
Maximum Ship Length	1600	1600	1500	1320	1500
Employment	22,000	6000	3000	6100	6500
Size (Acres)	250	250	200	200	170
New or Redeveloped	N/M	M	N	M	M

Discussion

There are five foreign yards roughly comparable to Newport News, particularly the new commercial facility. The smallest yard was eliminated to obtain the required four.

SELECTION OF COMPARABLE YARDS

Criteria	Litton/Ingalls	Yard B	Yard F	Yard J	Yard S
Work Experience					
Past 10 years	B,D	A,B,D	A	A,B	A,B,D
Current	D	A,B	A,B	A,B	A,B,D
Maximum Ship Length	800	1800	1500	1500	1320
Employment	18,500	6000	3000	6500	6100
Size (Acres).	400	250	200	170	200
New or Redeveloped	N	M	N	M	M

Discussion

There are five foreign yards roughly comparable to the new Litton/Ingalls yard. One was eliminated on the basis of having lower technology than the other four.

SELECTION OF COMPARABLE YARDS

Criteria	Avondale	Yard A	Yard R	Yard D	Yard L
Work Experience					
Past 10 years	A,B,D	A,B	A,B,D	A,B	A
Current	A,B,C	A,B	B,D	A,B	A,B
Maximum Ship Length	1050	1100	1000	1170	1080
Employment	4300	3900	6000	5900	3500
Size (Acres)	218	95	100	90	250
New or Redeveloped	M	M	M	M	N

Discussion

There are five foreign yards roughly comparable to Avondale. One was eliminated on the basis that it was smaller than Avondale and had lower technology than the other four.

SELECTION OF COMPARABLE YARDS

Criteria	Levingston	Yard E	Yard A	Yard M	Yard C
Work Experience					
Past 10 years	A,B	B,C,D	A,B	A,B,C	A,B,C
Current	A,B	B,C,D	A,B	A,B,D	A,B,C
Maximum Ship Length	700	680	1100	1020	850
Employment	1700	2500	3900	5500	2600
Size (Acres)	80	35	95	120	50
New or Redeve oped	L	L	M	L	L

Discussion

The four foreign yards selected for comparison with Levingston have been principally chosen because of their experience on similar types of work. While these yards have medium level technology, the best of their type are included.

SELECTION OF COMPARABLE YARDS

Criteria	Natl Steel	Yard G	Yard II	Yard L	Yard R
Work Experience					
Past 10 years	A,B,C	A	A,D	A	A,B,D
Current	A ,C	A,B	D	A,B	D ,B
Maximum Ship Length	980	1360	1150	1080	1000
Employment	5500	5700	3600	3500	6000
Size (Acres)	145	210	40	250	100
New or Redeveloped	M	N	M	N	M

Discussion

There are five foreign yards roughly comparable to National Steel. The one eliminated has less specialized steel production facilities and is less suited to series production.

SELECTION OF COMPARABLE YARDS

Criteria	Todd, L.A.	Yard N	Yard C	Yard D	Yard M
Work Experience					
Past 10 years	A,D	A,B,D	A,B,C,D	A,B	A,B,C
Current	D	B,D	A,B,C,D	A,B	A,B,D
Maximum Ship Length	600	1000	850	1170	1020
Employment	2000	5400	2600	5900	5500
Size (Acres)	60	100	50	90	120
New or Redeveloped	L	M	L	M	L

Discussion

There are five foreign yards roughly comparable to odd, Los Angeles. One yard was eliminated to provide a better international balance among the remaining four.

SELECTION OF COMPARABLE YARDS

Criteria	Todd, Seattle	Yard K	Yard C	Yard E	Yard M
Work Experience					
Past 10 years	A,B,D	A,B	A,B,C,D	B,C,D	A,B,C
Current	D	A,B	A,B,C,D	B,C,D	A,B,D
Maximum Sh p Length	0	800	850	680	1020
Employment	1800	3900	2600	2500	5500
Size (Acres	35	65	50	35	120
New or Redeveloped	L	L	L	L	L

Discussion

There are five foreign yards roughly comparable to Todd, Seattle. One yard p ializing in high steel throughput was eliminated.

SELECTION OF COMPARABLE YARDS

Criteria	Lockheed	Yard M	Yard K	Yard C	Yard N
Work Experience					
Past 10 years	A,B,C	A,B,C	A,B	A,B,C,D	A,B,D
Current	C	A,B,D	A,B	A,B,C,D	B,D
Maximum Ship Length	700	1020	800	850	1000
Employment	2500	5500	3900	2600	5400
Size (Acres)	100	120	65	50	100
New or Redeveloped	L	L	L	L	M

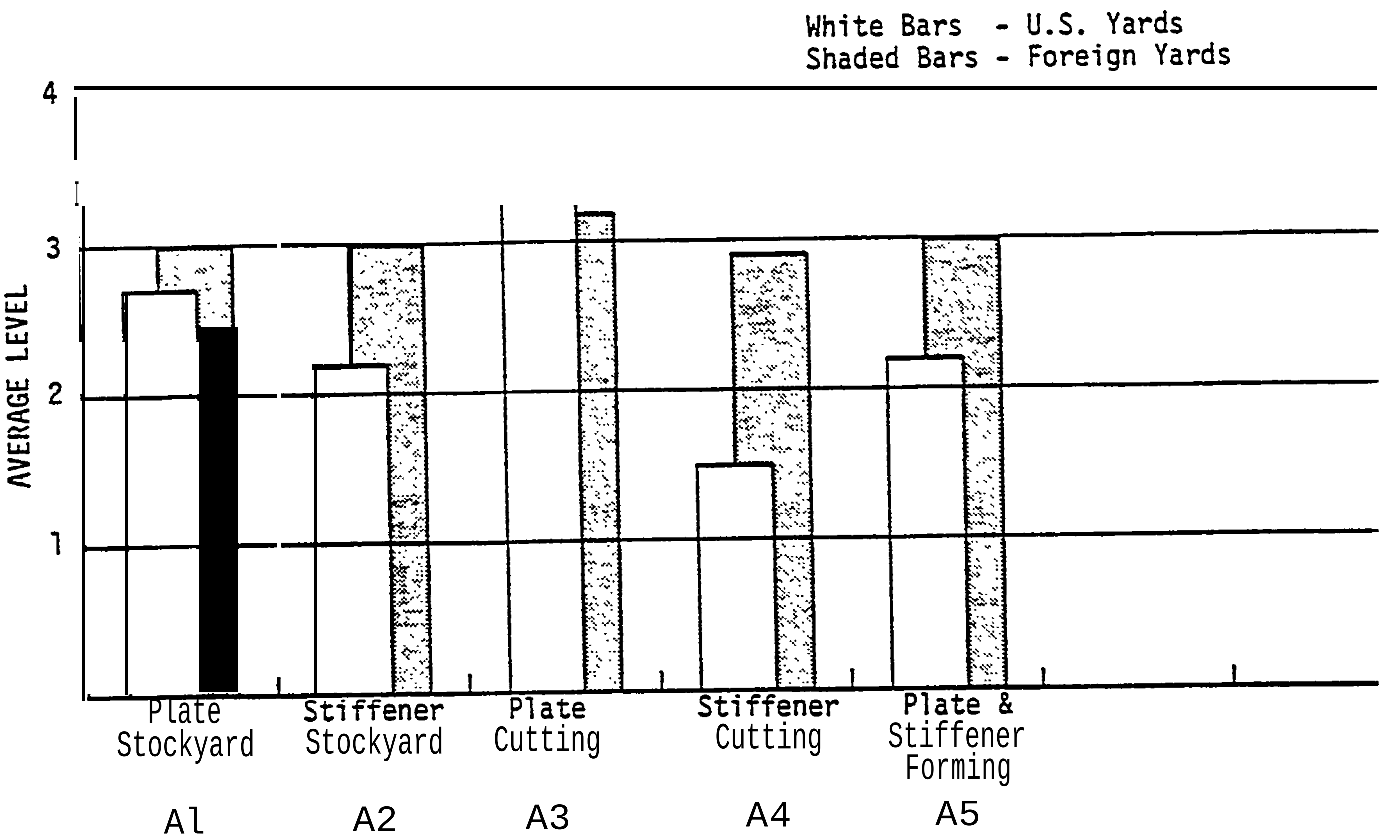
Discussion

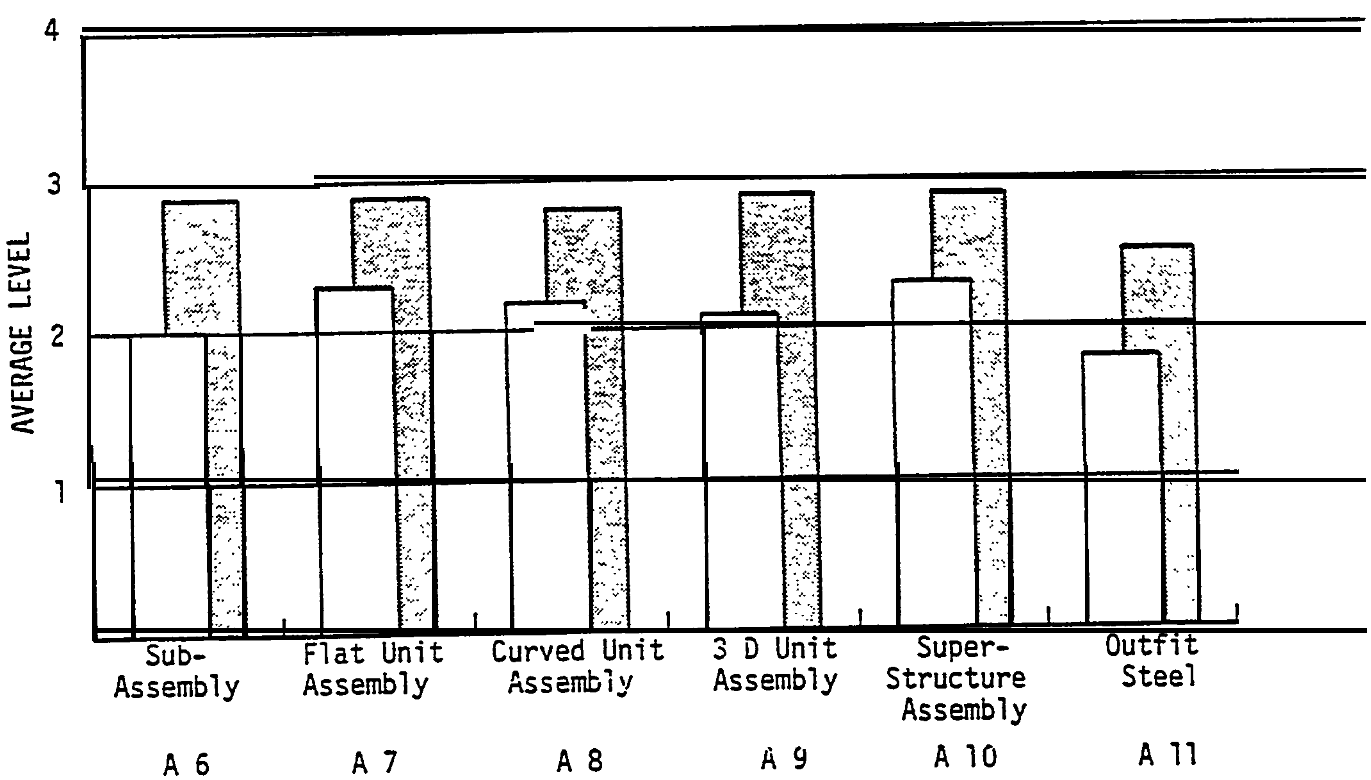
Four foreign yards are roughly comparable to Lockheed and have been selected for the comparison.

APPENDIX G

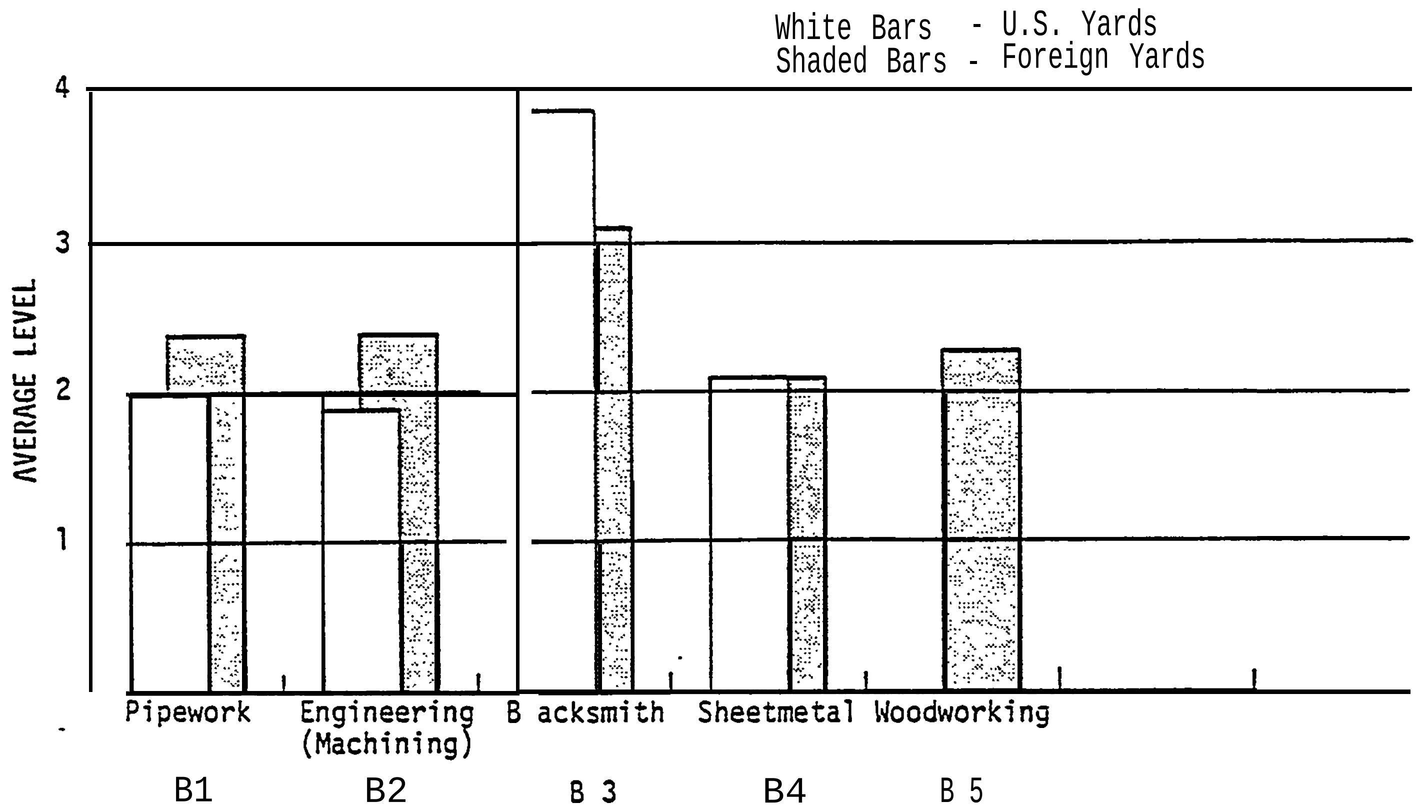
COMPARISON OF AVERAGE TECHNOLOGY OF LEVELS BY ELEMENT

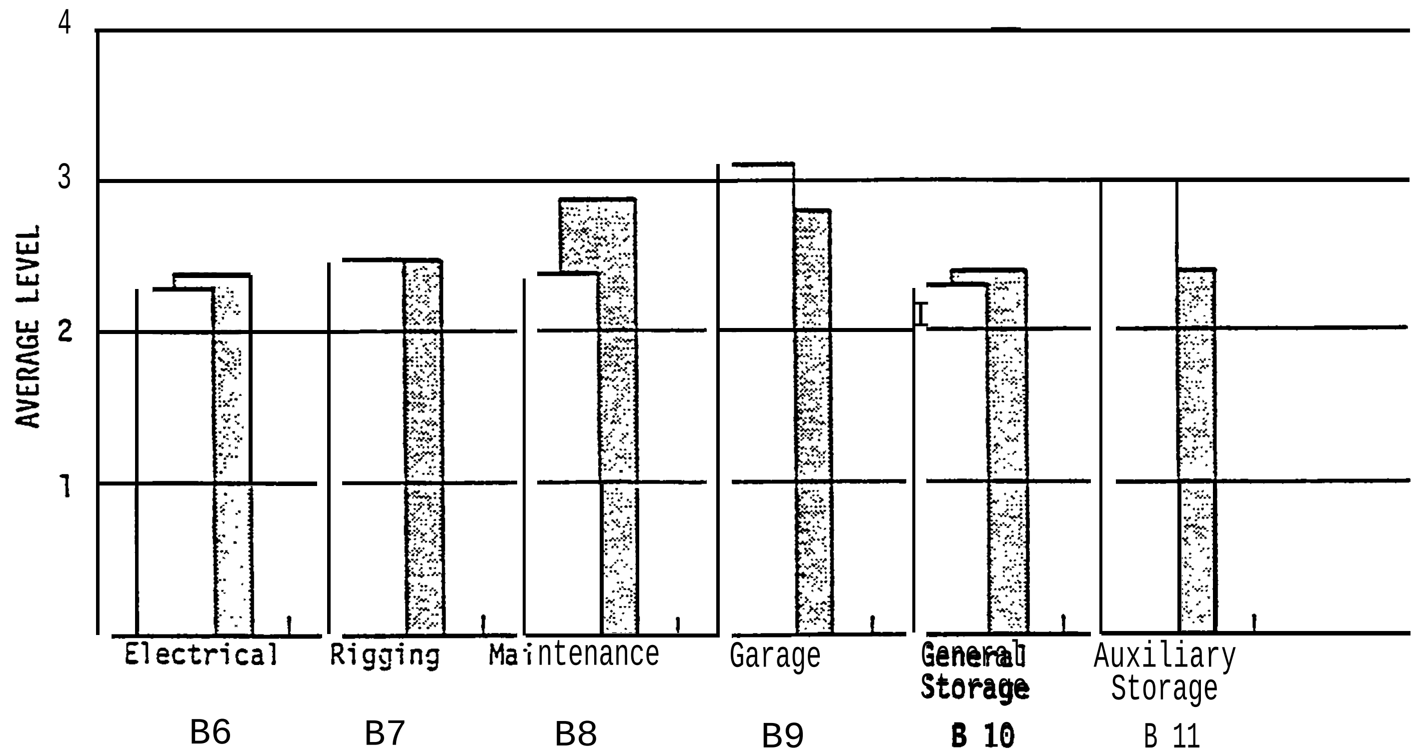
A STEELWORK PRODUCTION



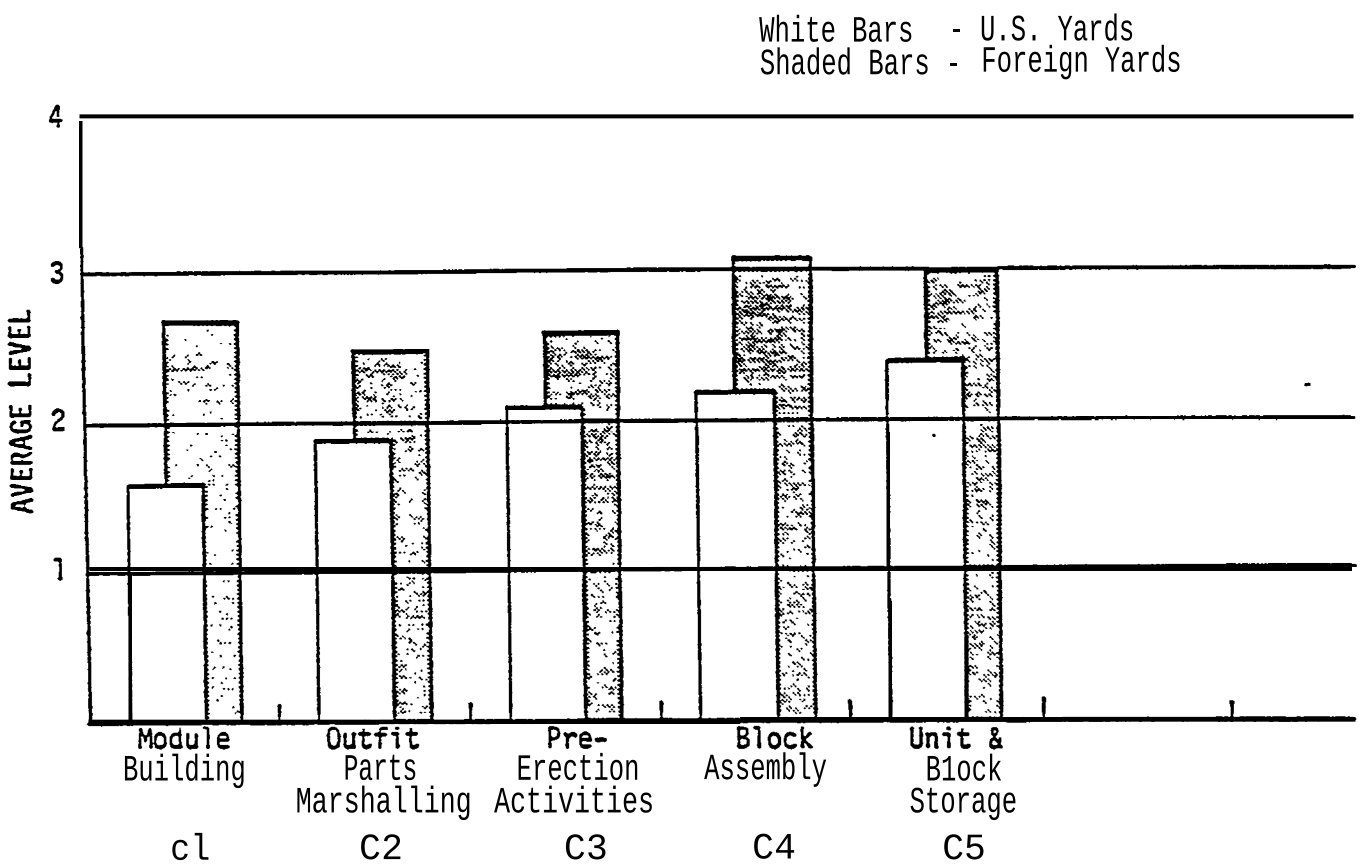


B OUTFIT PRODUCTION & STORES

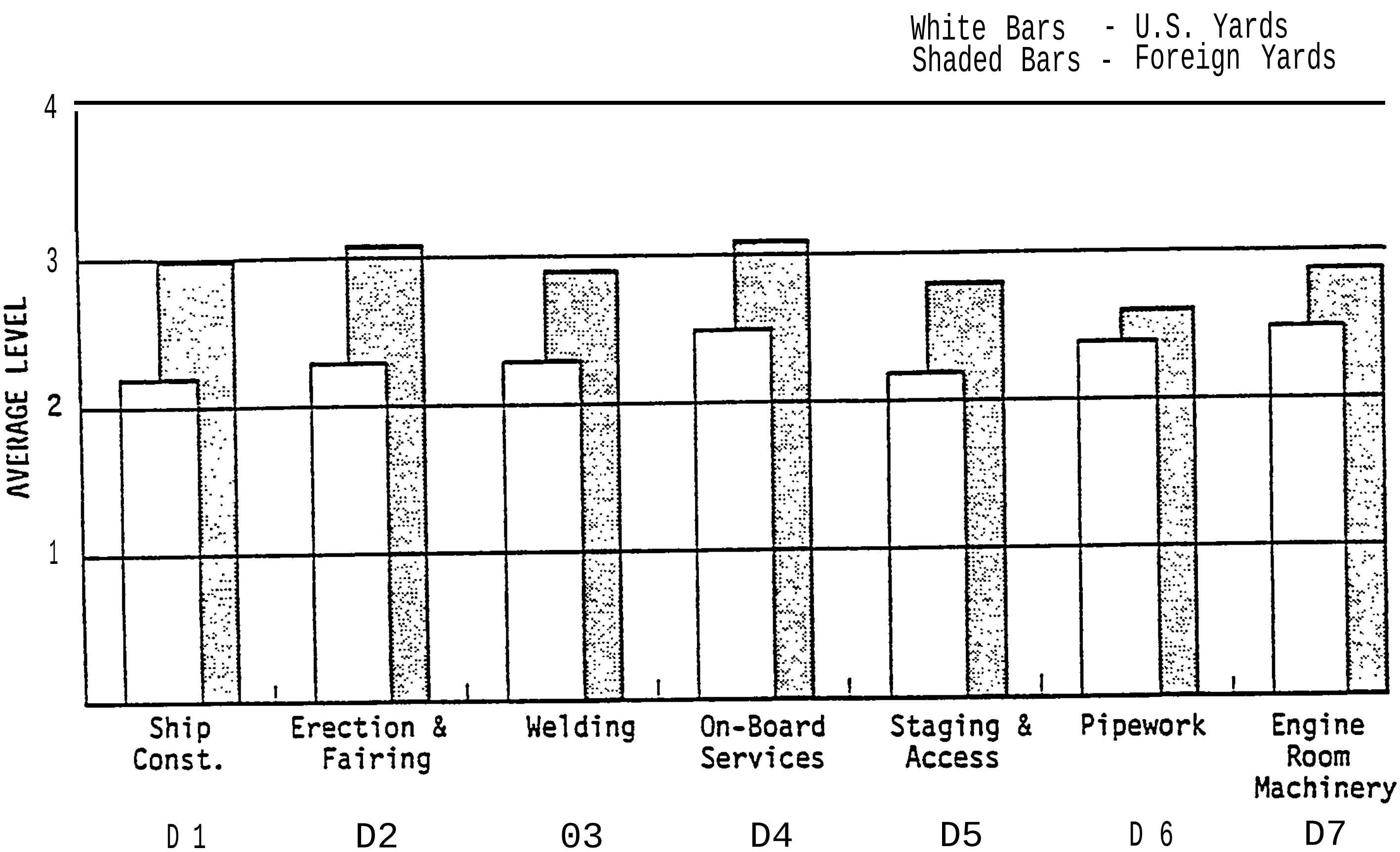


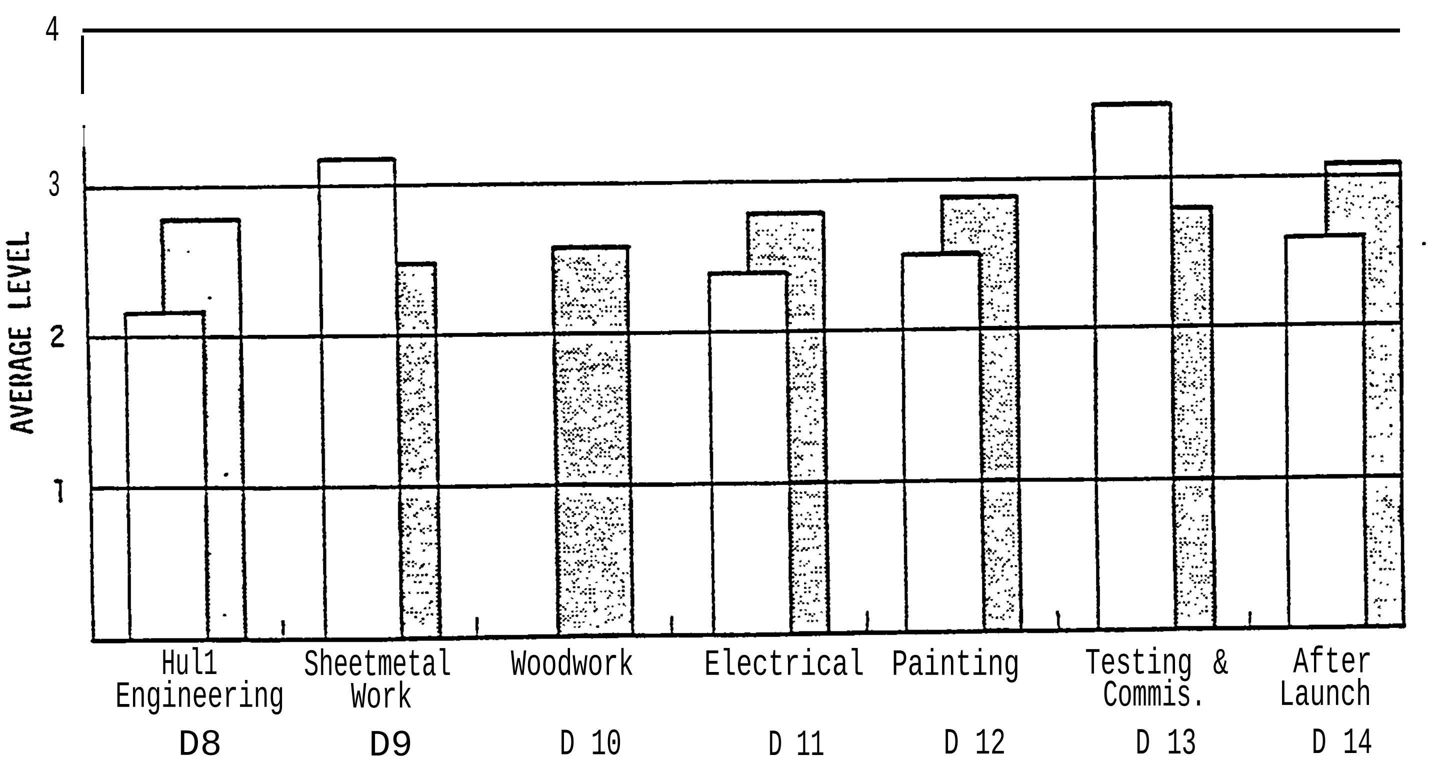


C OTHER PRE-ERECTION ACTIVITIES

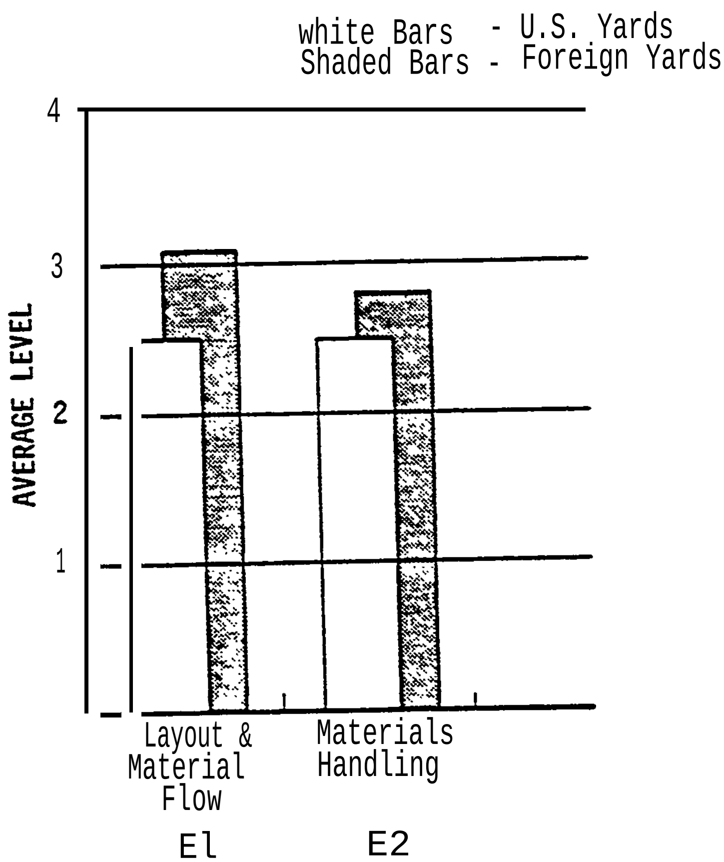


D SHIP CONSTRUCTION & INSTALLATION

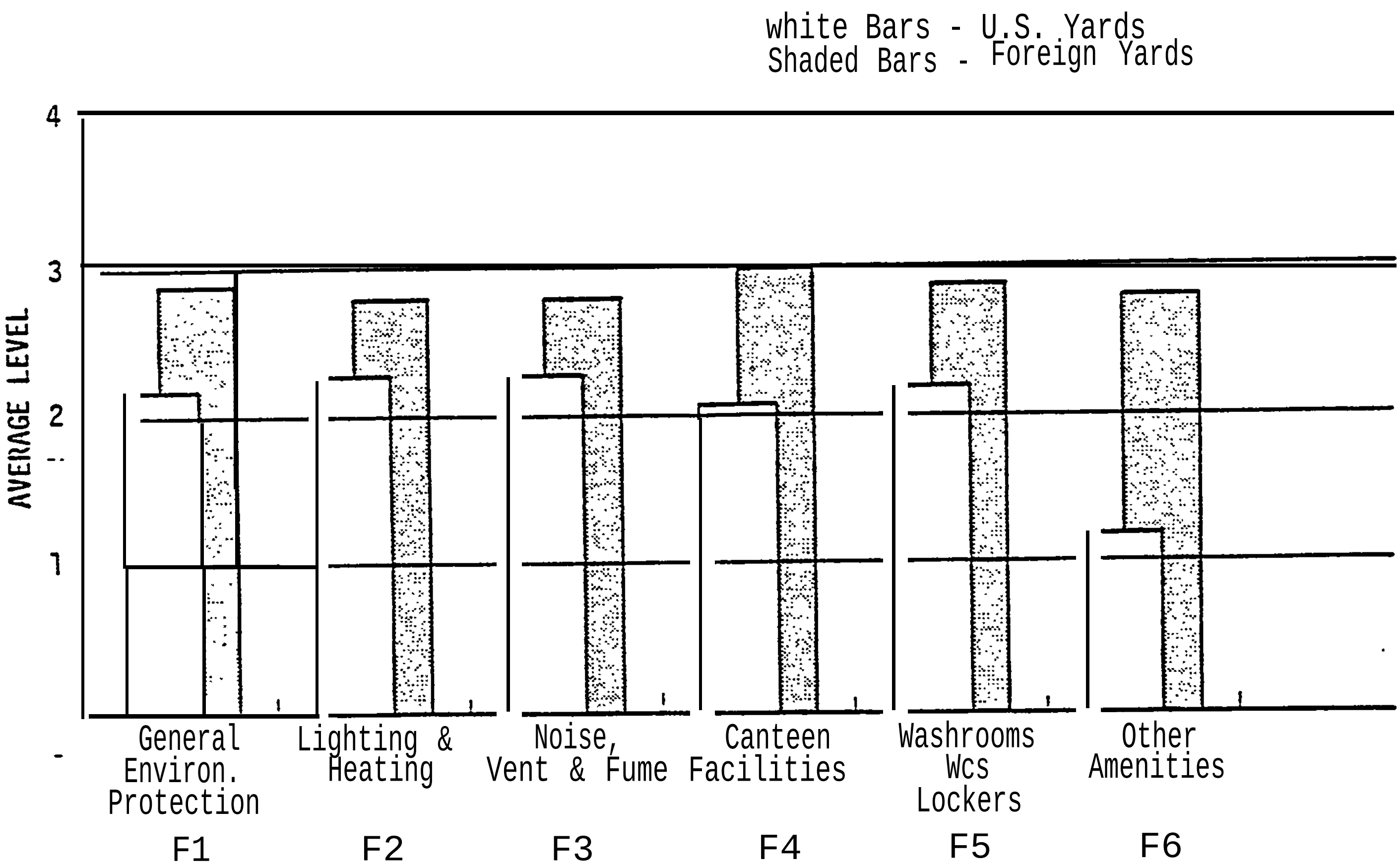




E LAYOUT & MATERIALS HANDLING



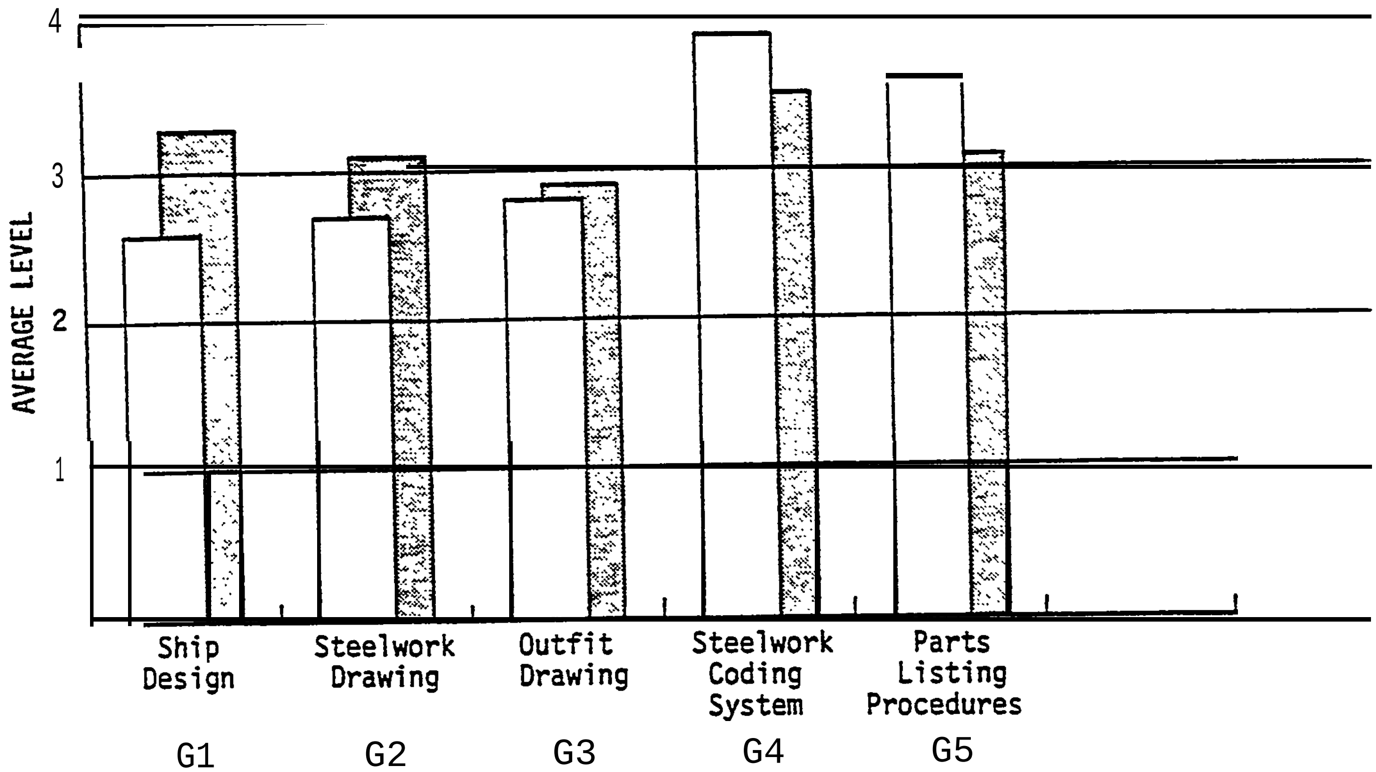
F AMENITIES

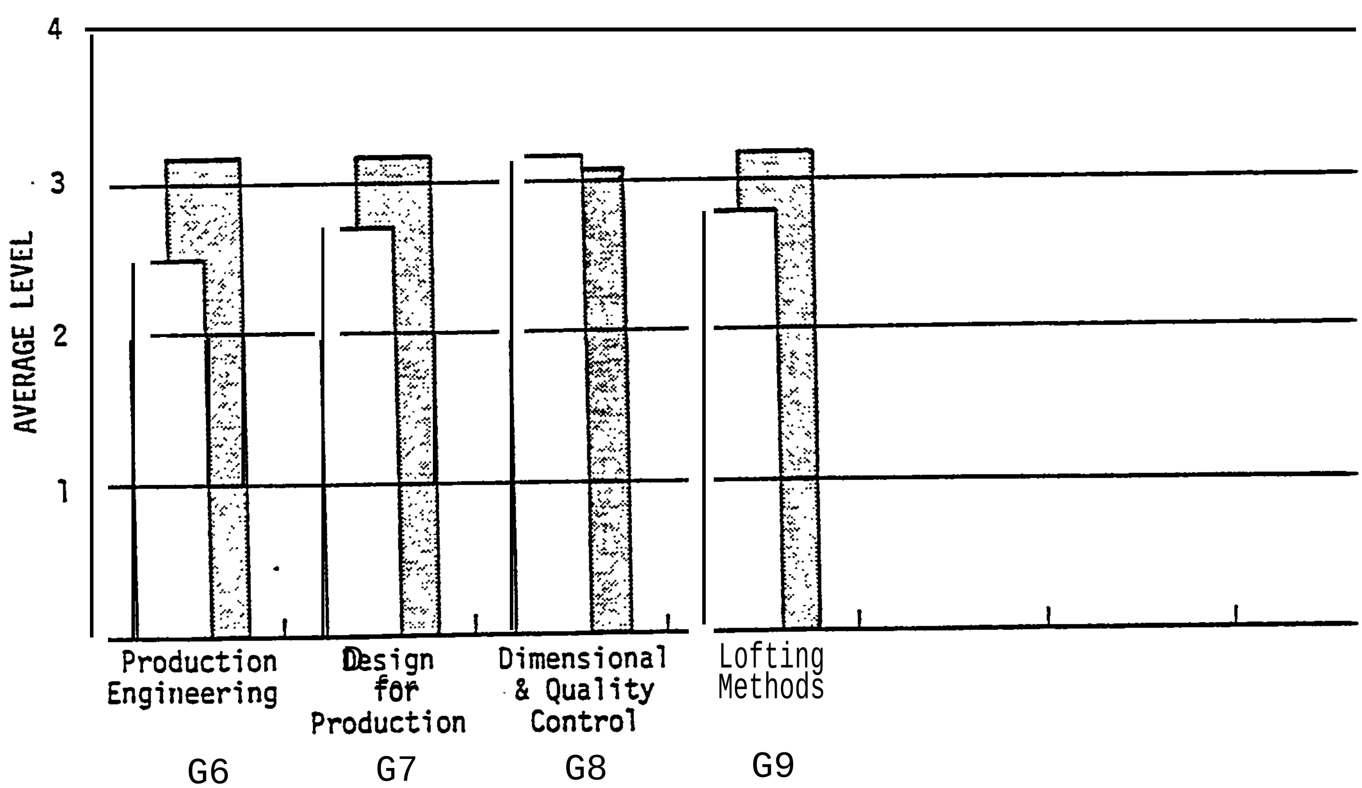


White Bars - U.S. Yards
Shaded Bars - Foreign Yards
4
3
2
1
AVERAGE LEVEL
General Environ. Protection
Lighting & Heating
Noise, Vent & Fume
Canteen Facilities
Washrooms WCs Lockers
Other Amenities
F1
F2
F3
F4
F5
F6

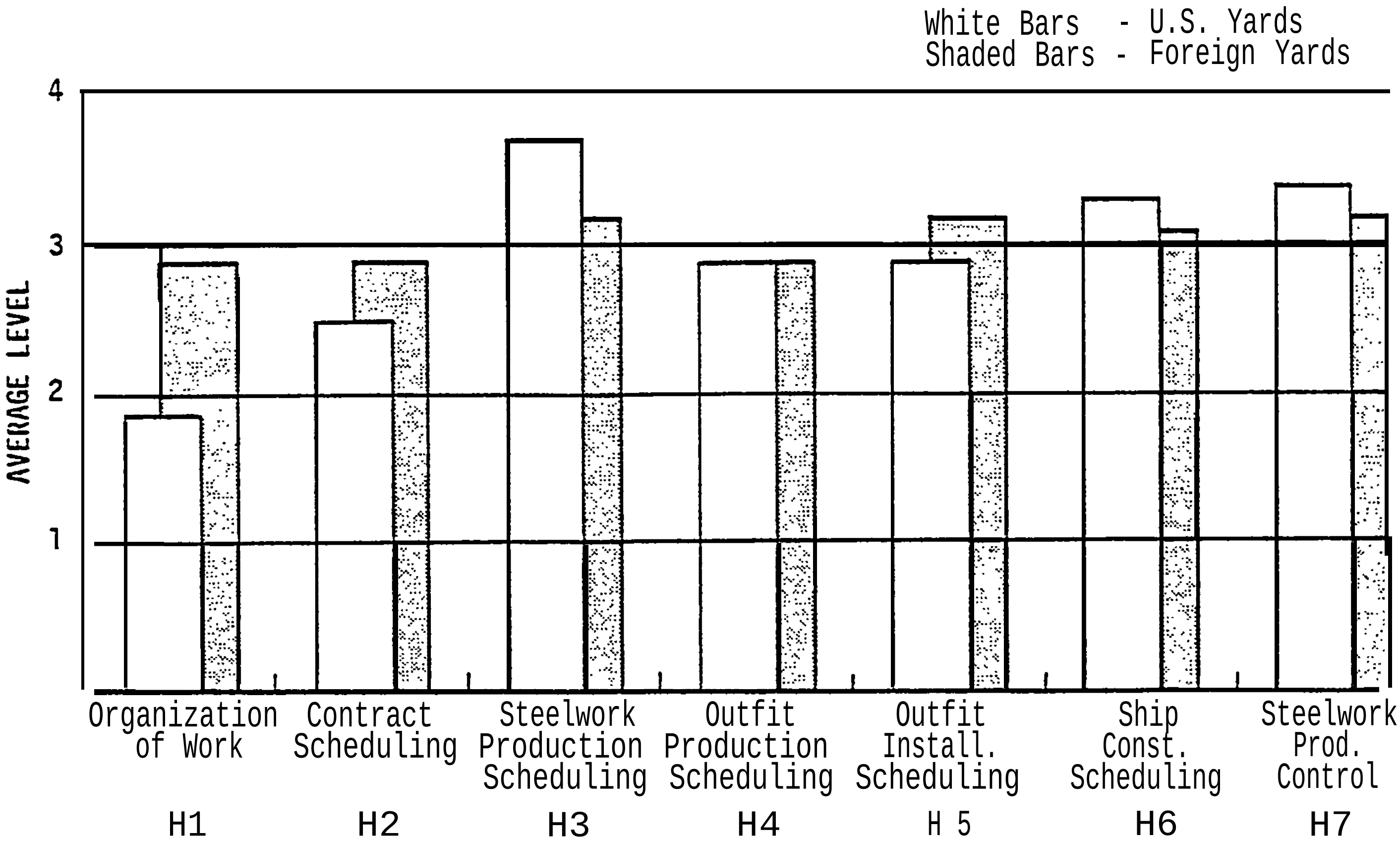
G DESIGN, DRAFTING, PRODUCTION ENGINEERING & LOFTING

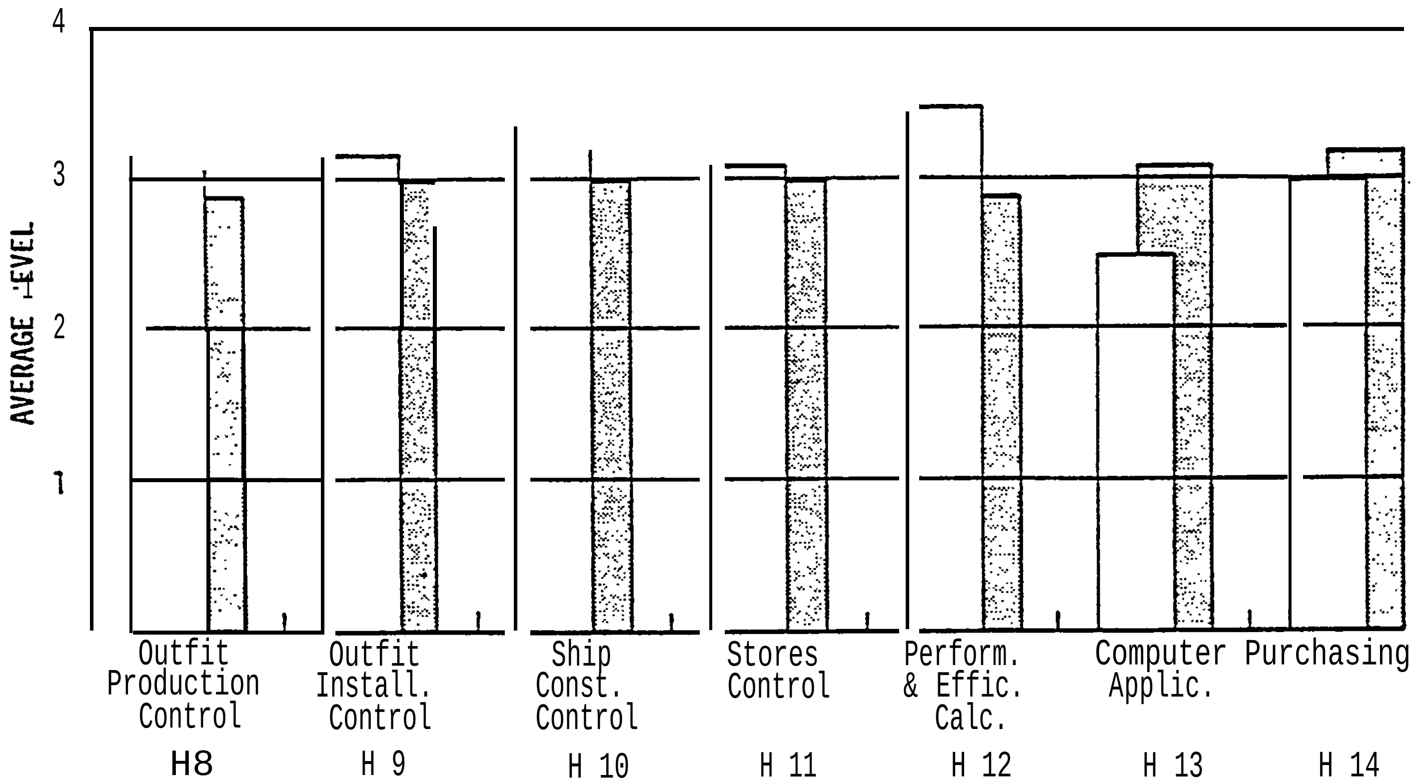
White Bars - U.S. Yards
Shaded Bars - Foreign Yards





H ORGANIZATION & OPERATING SYSTEMS





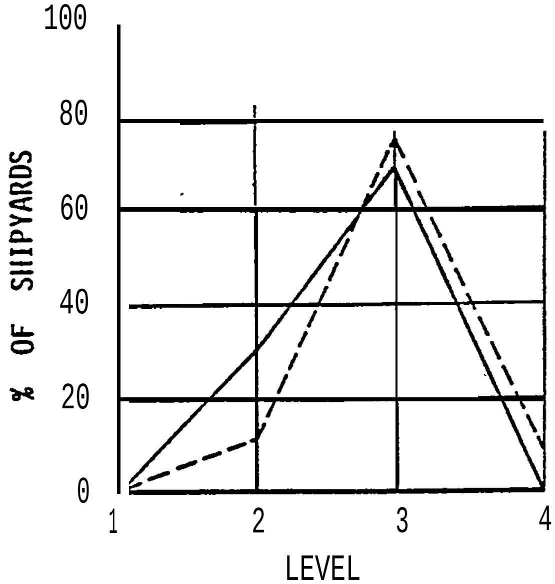
APPENDIX H

COMPARISON OF ACTUAL TECHNOLOGY LEVELS BY ELEMENTS

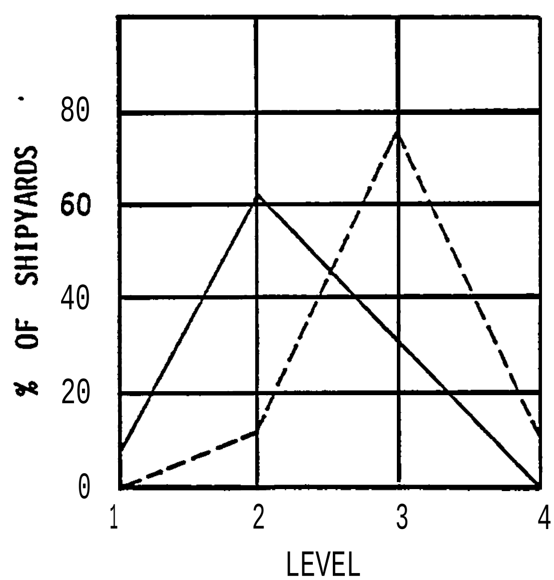
A STEELWORK PRODUCTION

— U.S. Yards
---- Foreign Yards

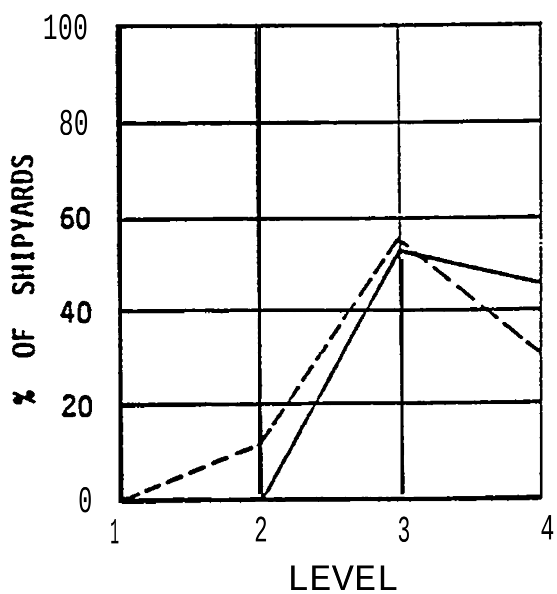
A1
Plate Stockyard
& Treatment



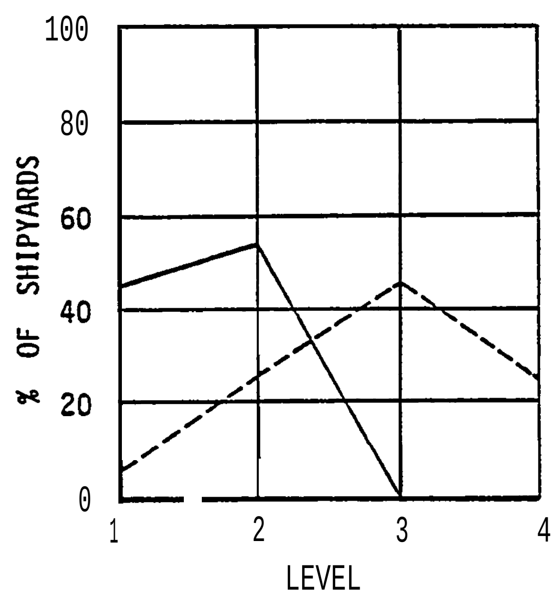
A2
Stiffener Stockyard
& Treatment



A 3
Plate
Cutting



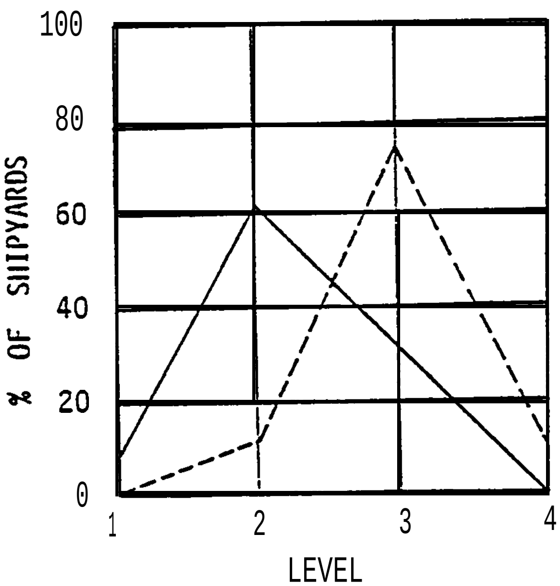
A 4
Stiffener
Cutting



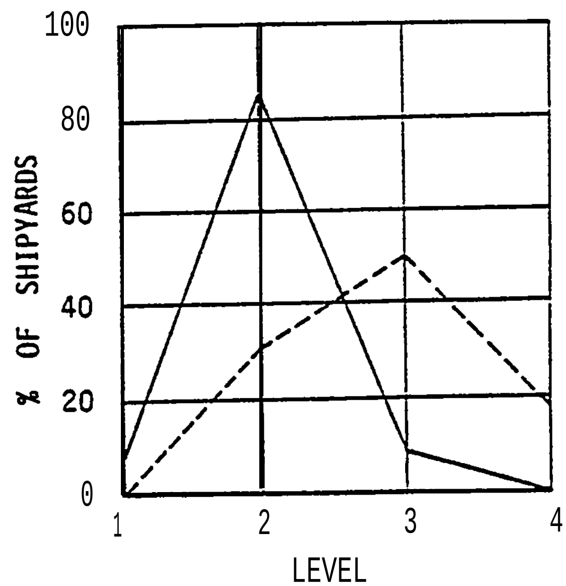
A STEELLWORK PRODUCTION
(Continued)

U.S. Yards
---- Foreign Yards

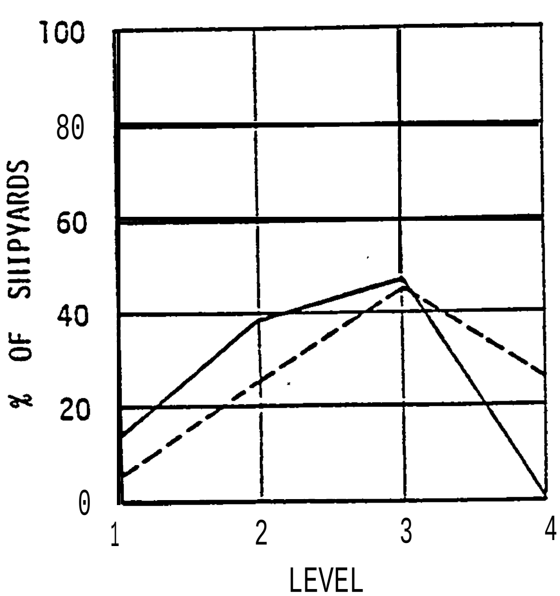
AS
Plate & Stiffener
Forming



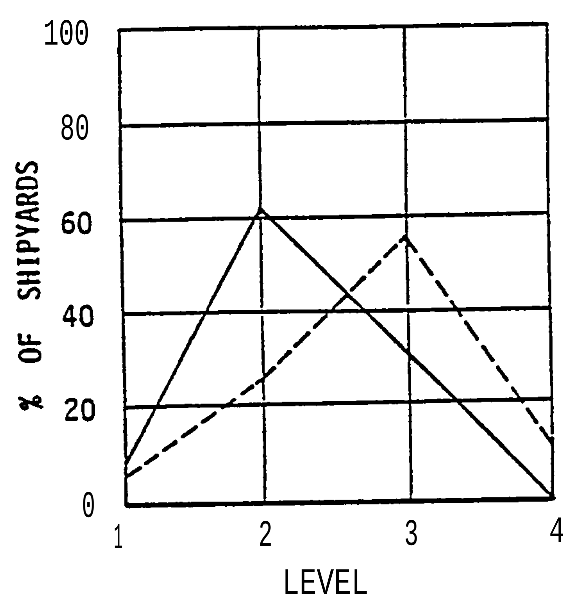
A6
Sub-
Assembly



A 7-
Flat Unit
Assembly



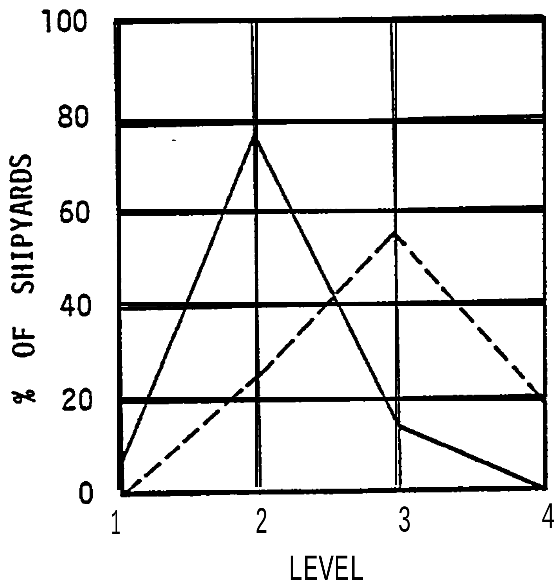
A8
Curved Unit
Assembly



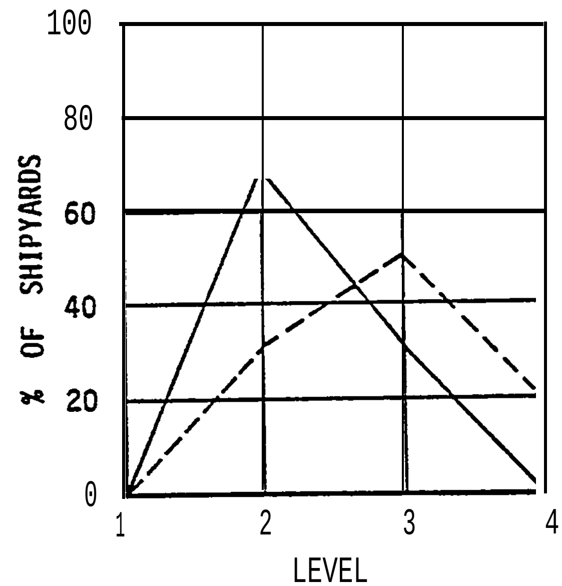
A STEELWORK PRODUCTION
(Continued)

—U.S. Yards
Foreign Yards

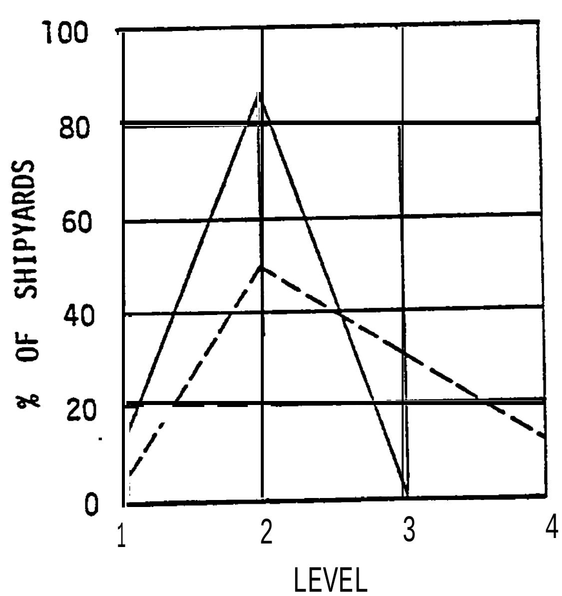
A9
3 D Unit
Assembly



A 10
Superstructure
Assembly



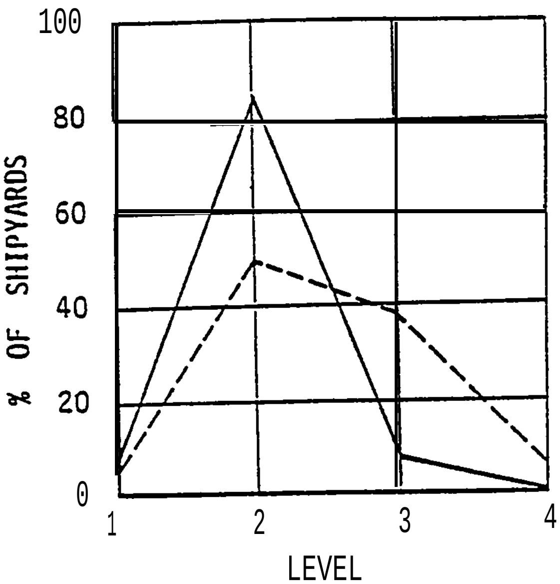
A 11
Outfit
Steel



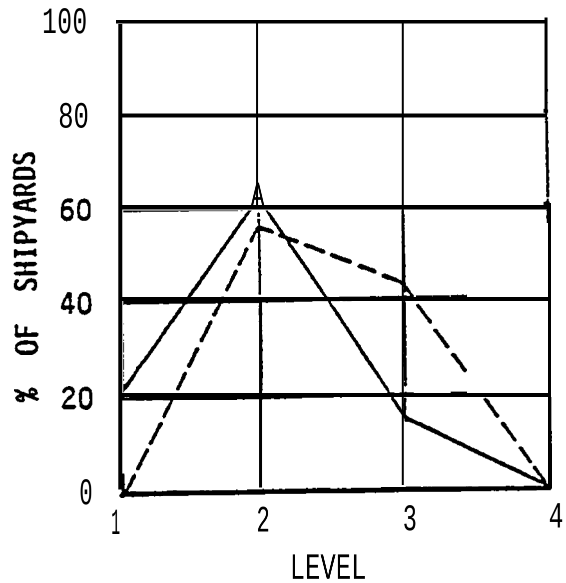
B OUTFIT PRODUCTION & STORES

—U.S. Yards
----Foreign Yards

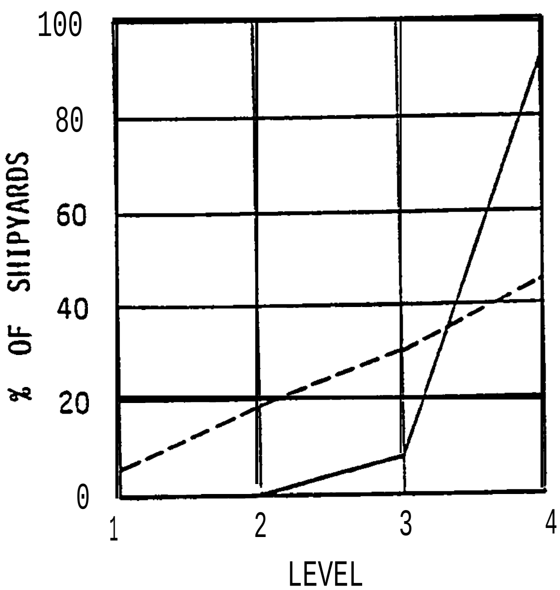
B 1
Pipework



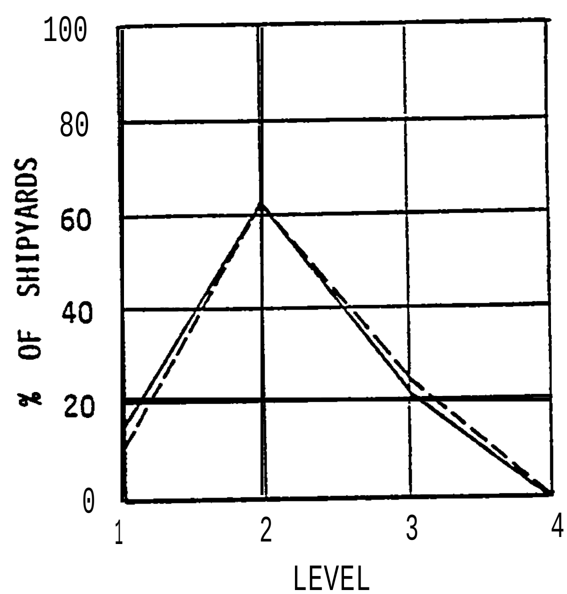
B2
Engineering
(Machining)



B 3
Blacksmith



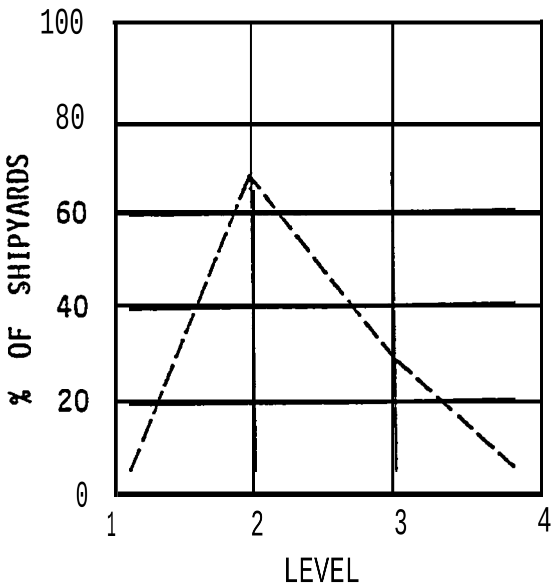
B4
Sheetmetal



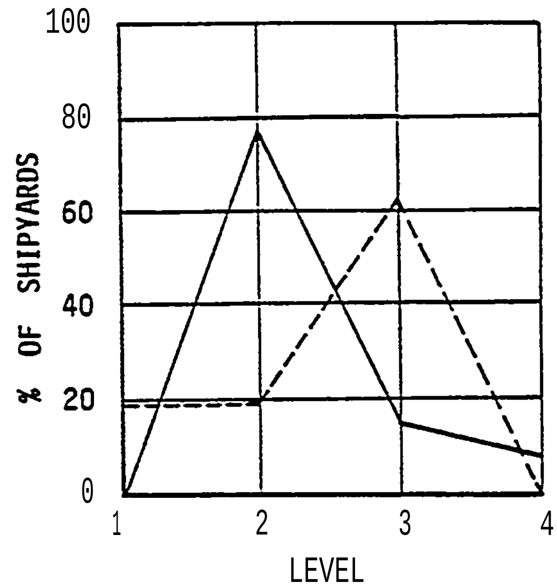
B OUTFIT PRODUCTION & STORES
(Continued)

—U.S. Yards
----Foreign Yards

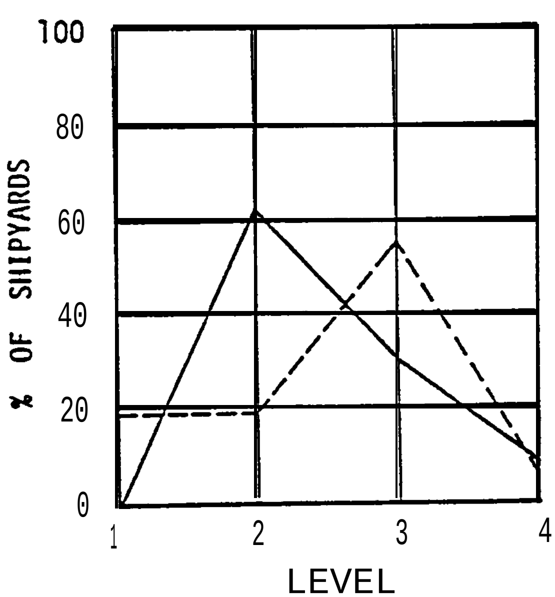
B5
Woodworking



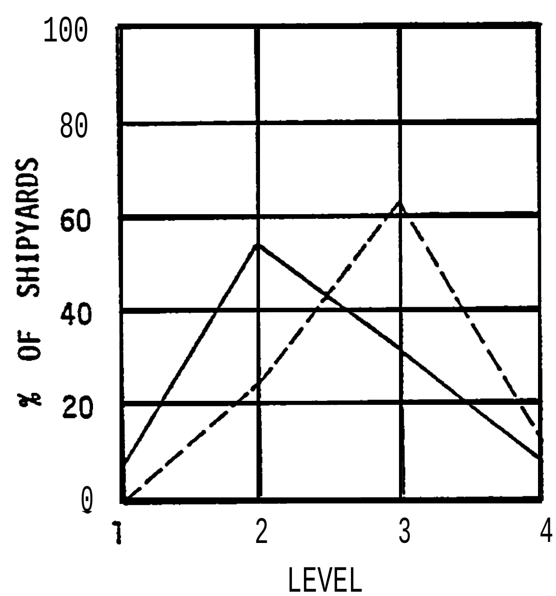
B6
Electrical



B7
Rigging



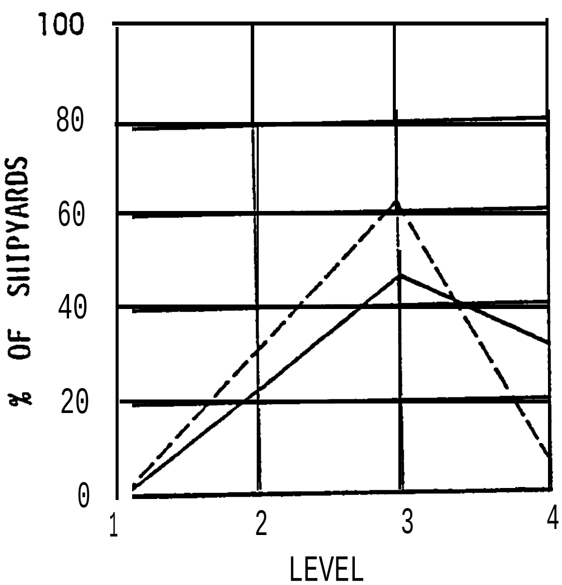
B8
Maintenance



— U. S. Yards
---- Foreign Yards

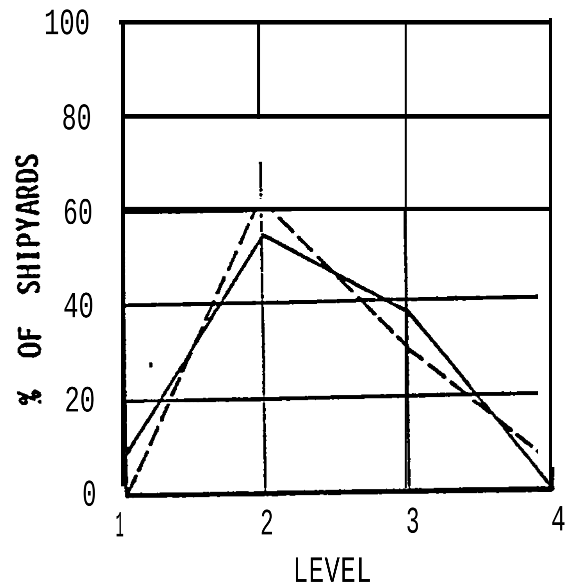
B9

Garage



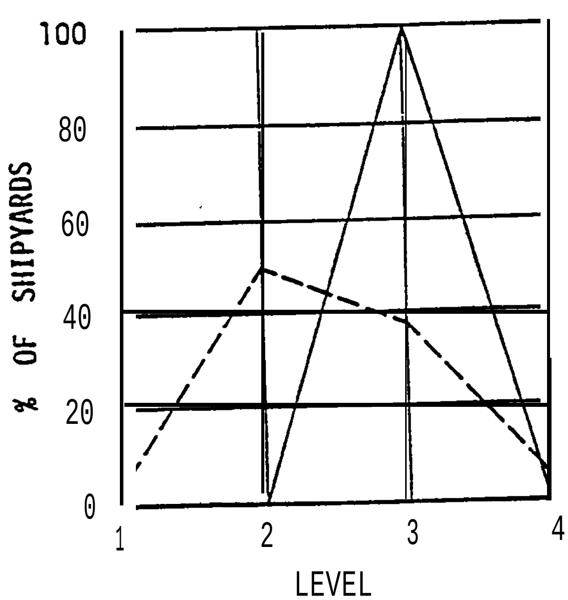
B 10

General
Storage



B 11

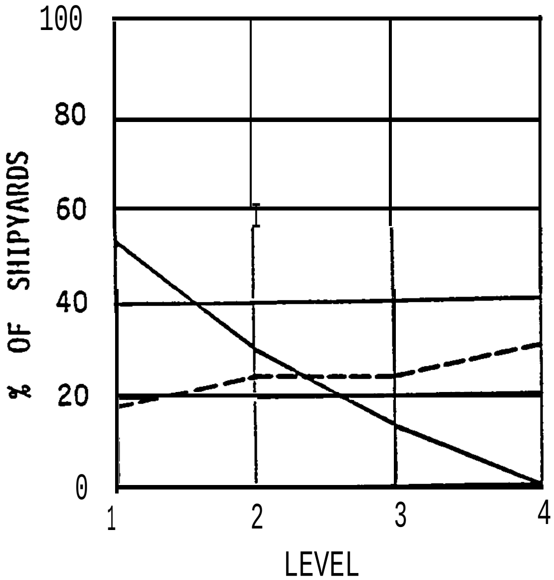
Auxiliary
Storage



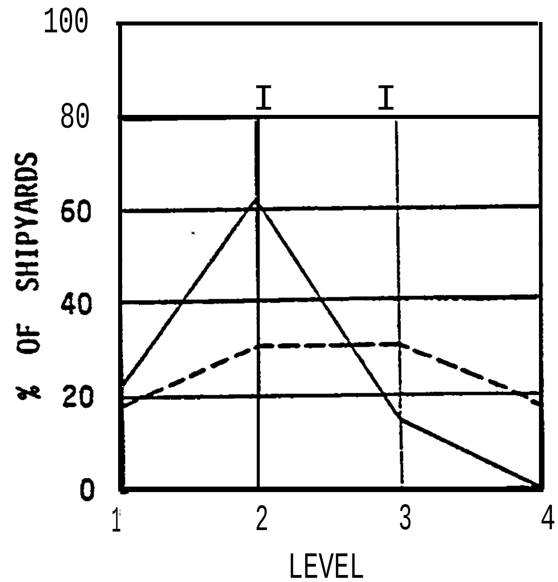
C OTHER PRE-ERECTION ACTIVITIES

U.S. Yards
Foreign Yards

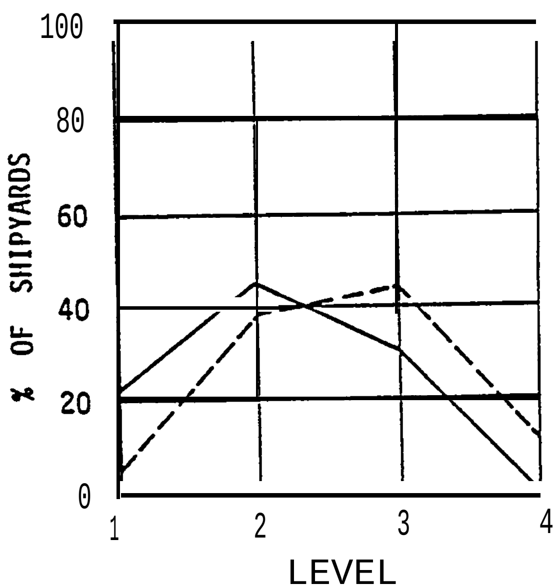
C1
Module
Building



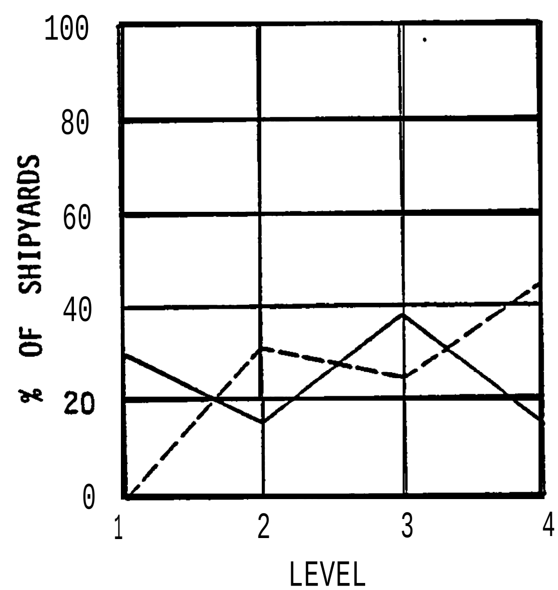
Outfit Parts
Marshalling



C3
Pre-erection
Activities



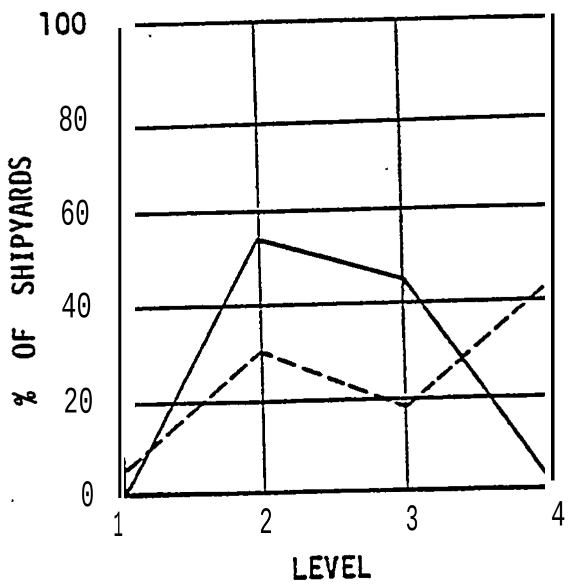
C4
Block
Assembly



C OTHER PRE-ERECTION ACTIVITIES
(Continued)

—U.S. Yards
---- Foreign Yards

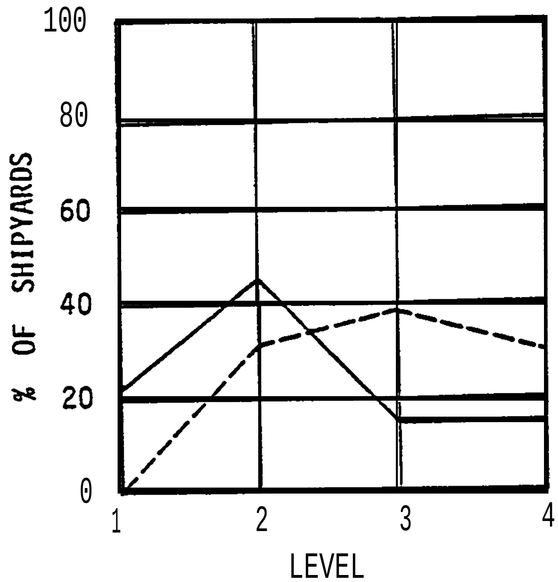
C5
Unit & Block
Storage



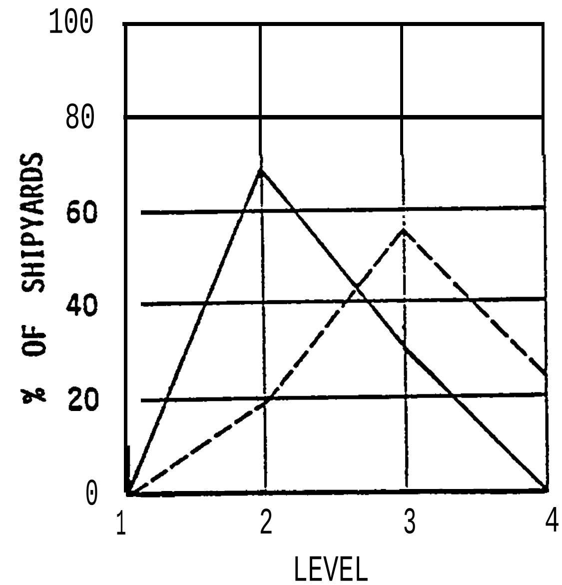
D SHIP CONSTRUCTION & INSTALLATION

—U.S. Yards
----Foreign Yards

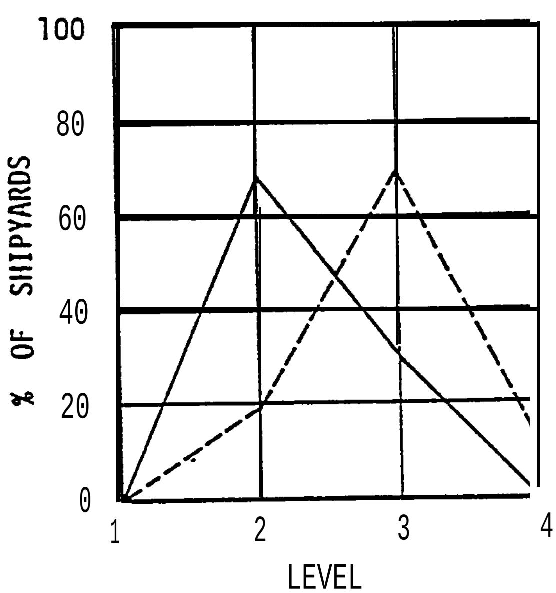
D1
Ship Construction



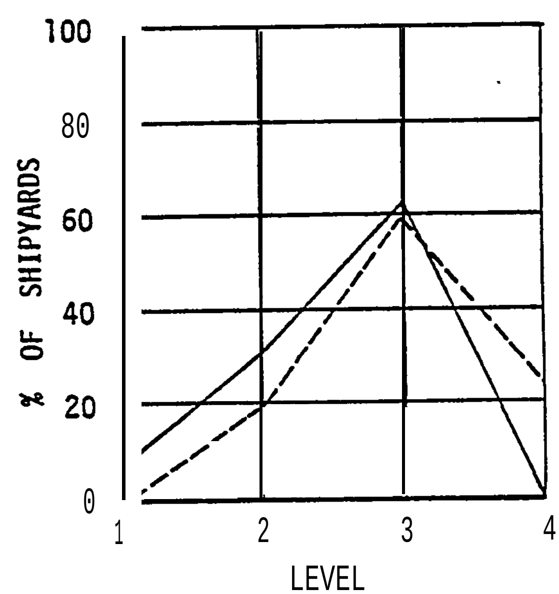
D2
Erection & Fairing



D 3
Welding



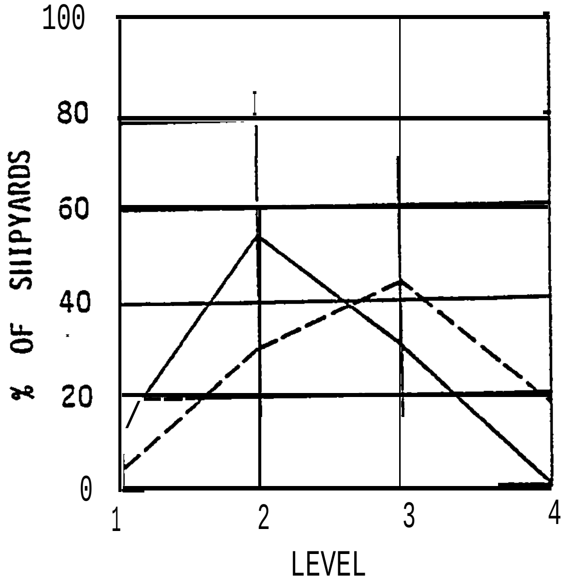
D4
On-board Services



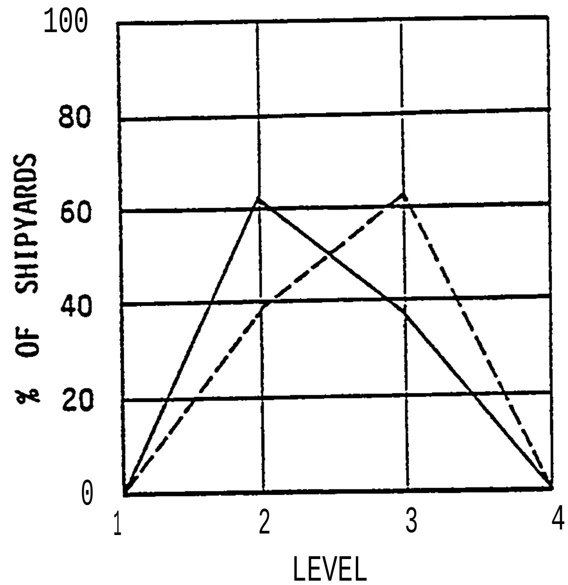
D SHIP CONSTRUCTION & INSTALLATION
(Continued)

—U.S. Yards
---- Foreign yards

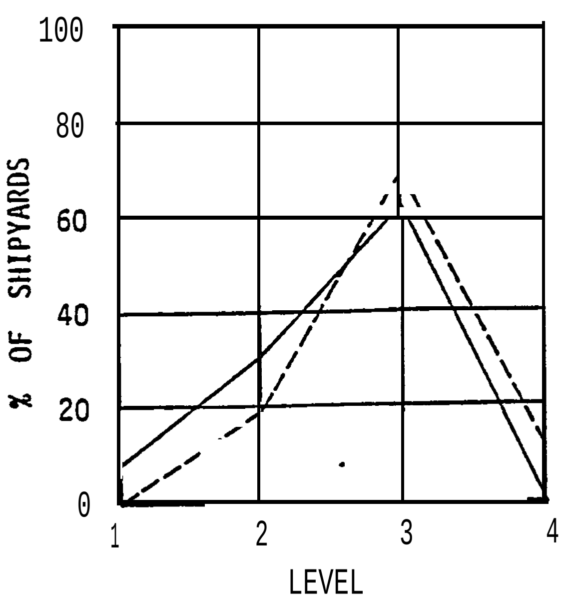
D5
Staging & Access



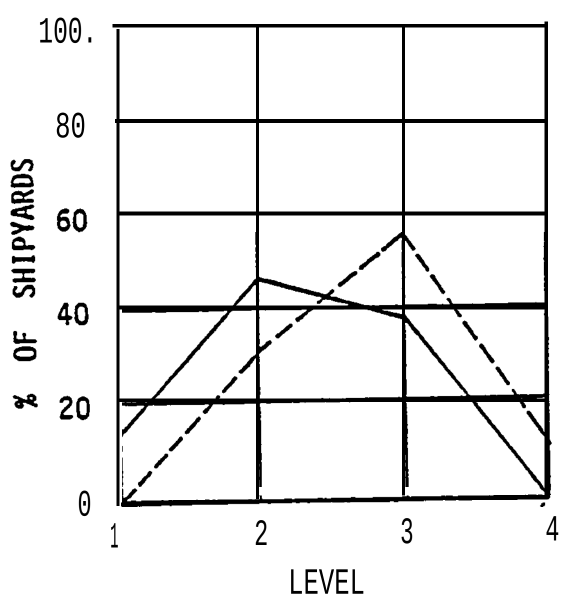
D6
Pipework



D7
Engine Room Machinery



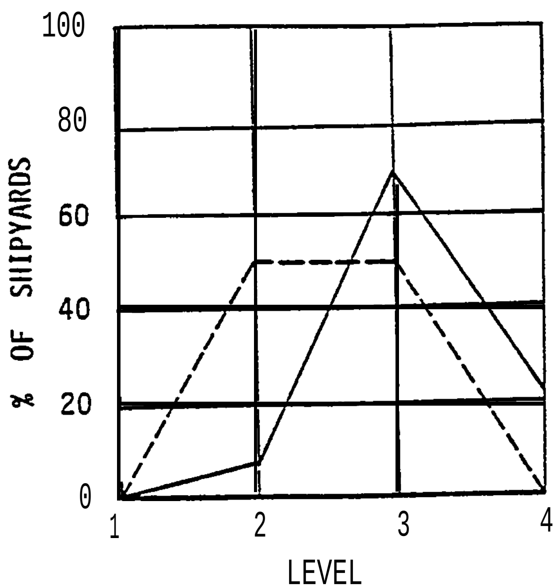
D8
Hull Engineering



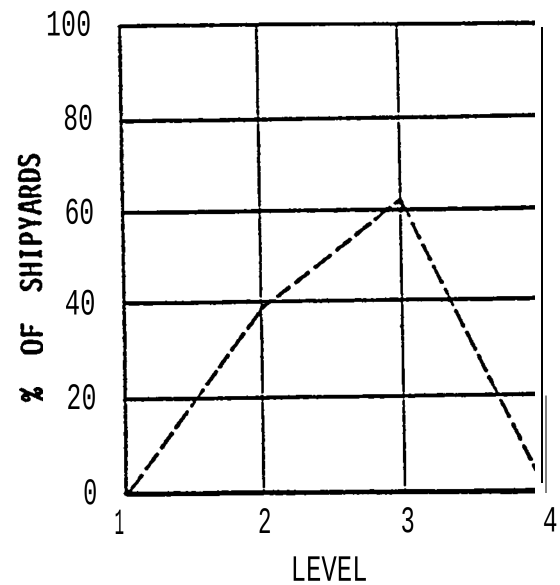
D SHIP CONSTRUCTION & INSTALLATION
(Continued)

— U.S. Yards
----Foreign Yards

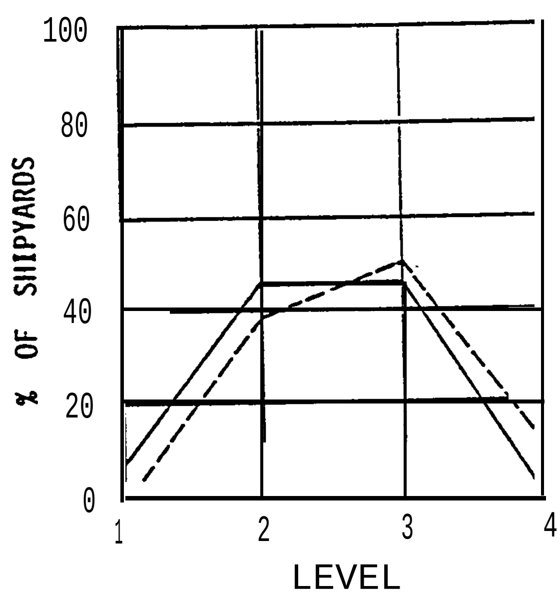
D 9
Sheetmetal Work



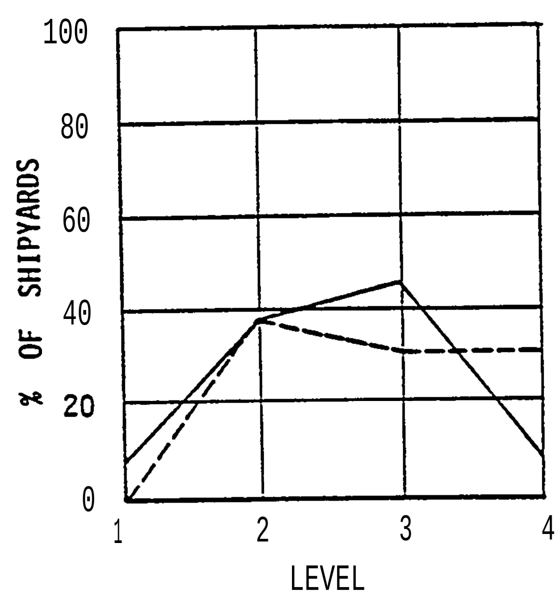
D 10
Woodwork



D 11
Electrical



D 12
Painting

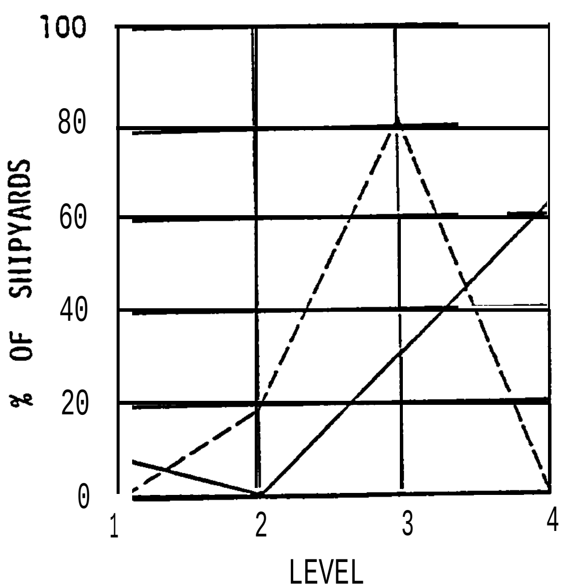


D SHIP CONSTRUCTION & INSTALLATION
(Continued)

— U.S. Yards
---- Foreign Yards

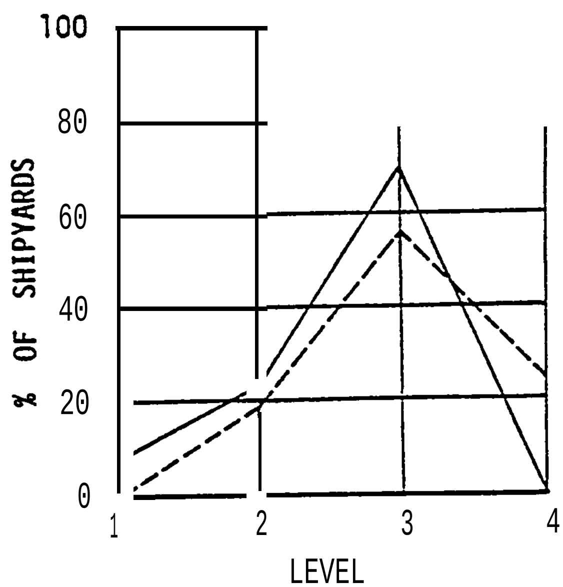
D 13

Testing &
Commissioning



D 14

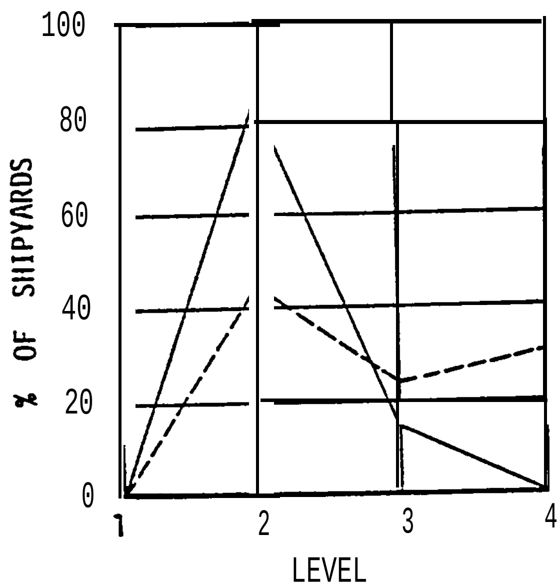
After
Launch



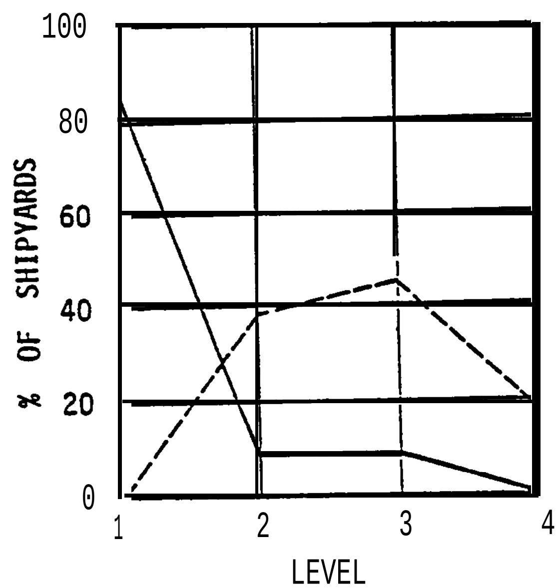
F AMENITIES
(Continued)

——— U.S. Yards
- - - - Foreign Yards

F5
Washrooms, W.C. s
Lockers



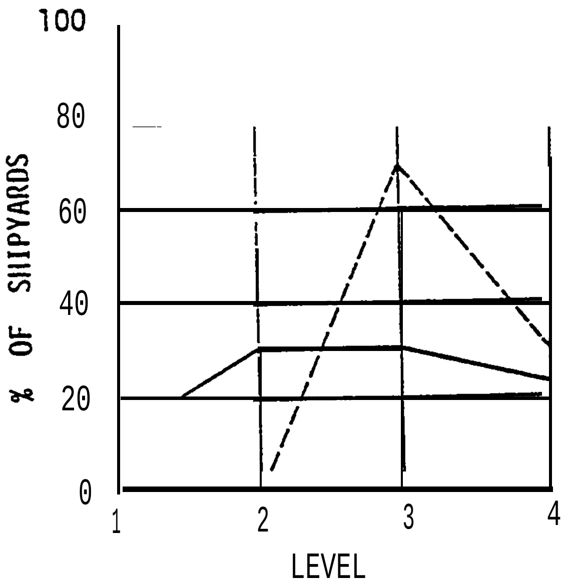
F6
Other
Amenities



G DESIGN, DRAFTING, PRODUCTION ENGINEERING & LOFTING

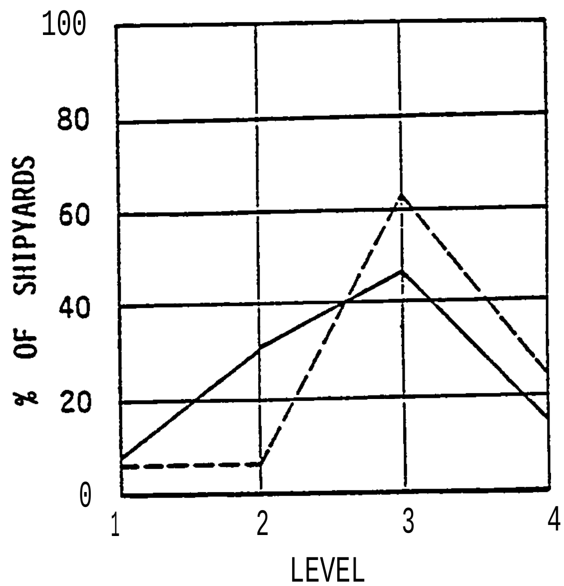
—U.S. Yards
----Foreign Yards

Ship
Design



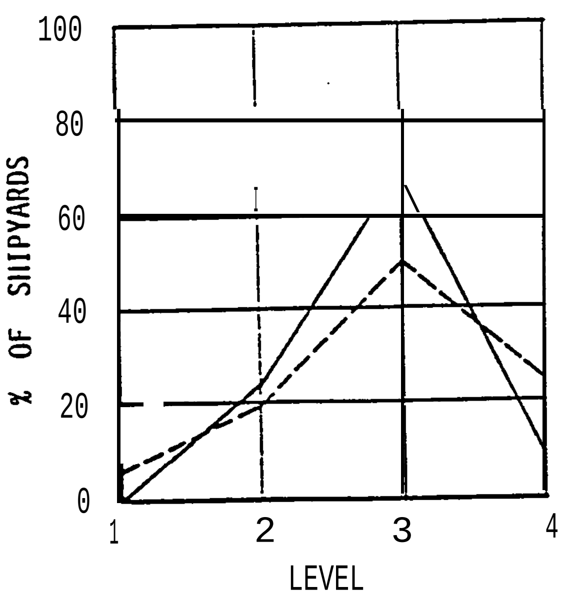
G 2

Steelwork
Drawing



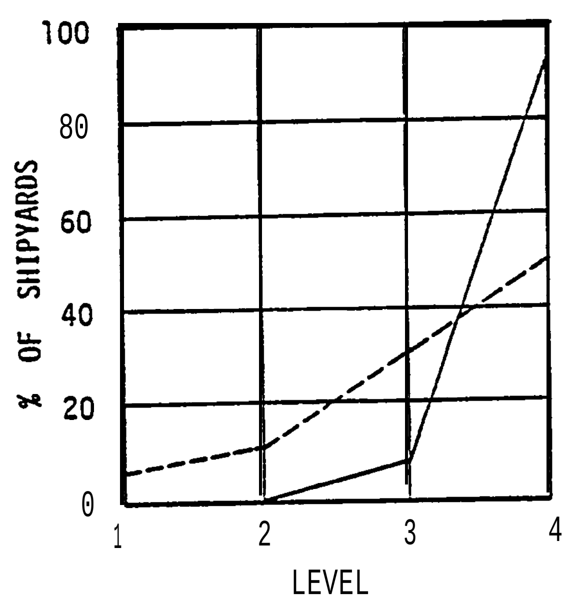
G3

Outfit
Drawing



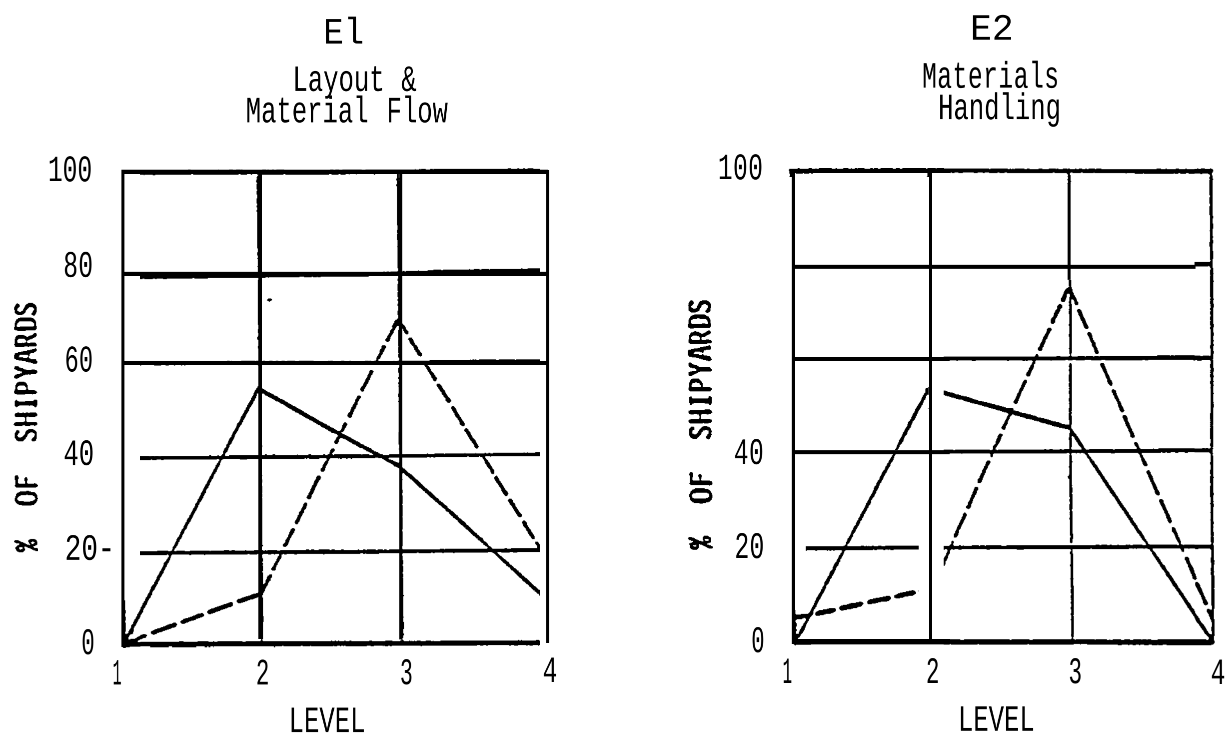
G4

Steelwork Coding
System



E LAYOUT & MATERIALS HANDLING

—U.S. Yards
----Foreign Yards

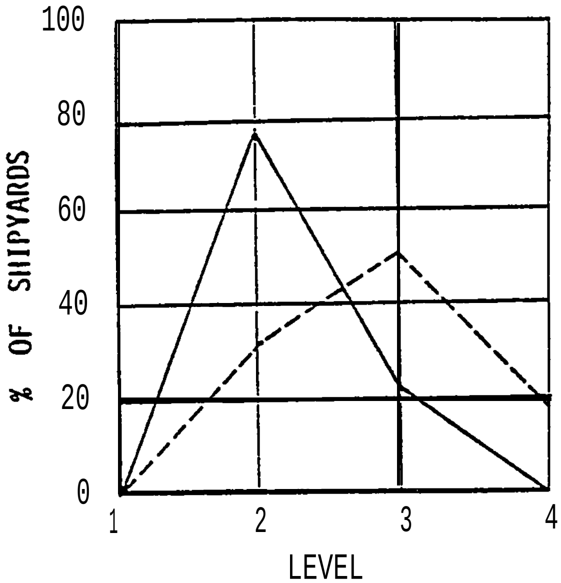


F AMENIFIES

—U.S. Yards
---- Foreign Yards

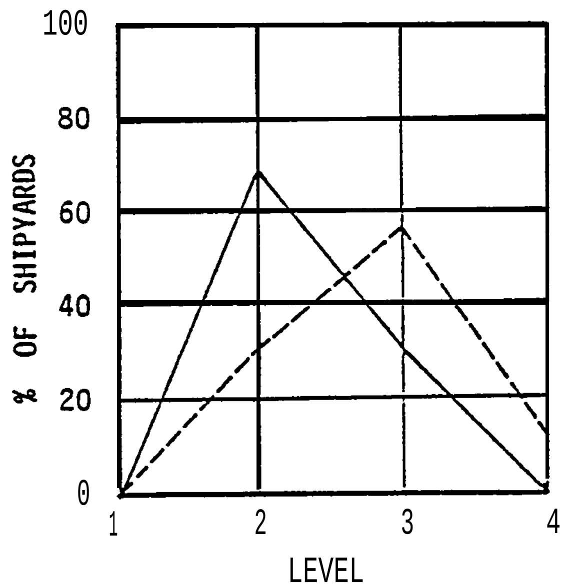
F1

General Environ. Protection



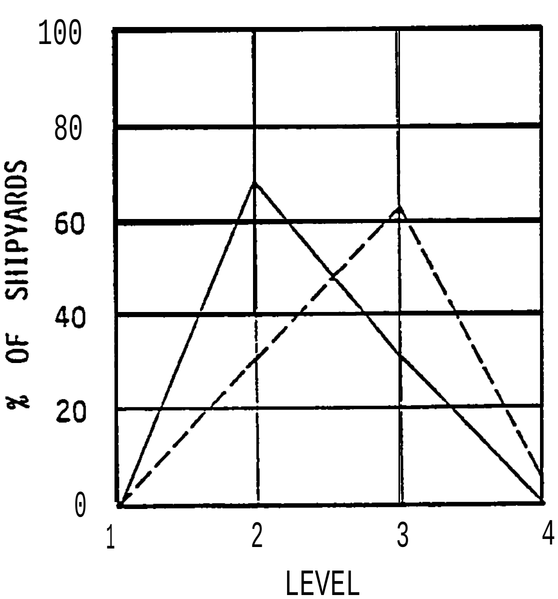
F2

Lighting & Heating



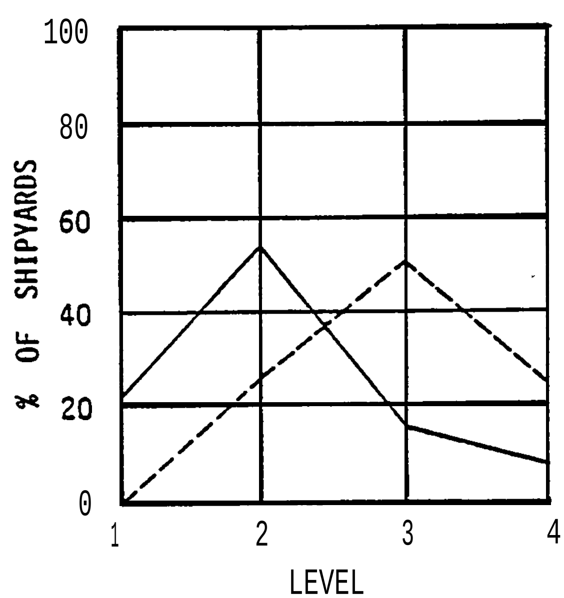
F3

Noise, Vent. & Fume Extraction



F4

Canteen Facilities

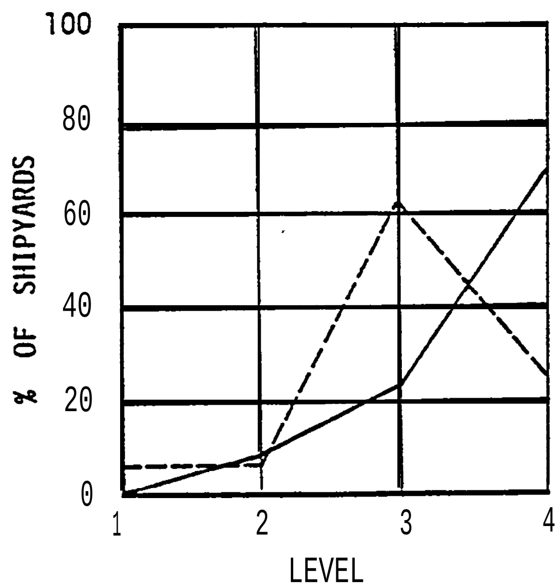


G DESIGN, DRAFTING, PRODUCTION ENGINEERING & LOFTING (Continued)

— U.S. Yards
---- Foreign Yards

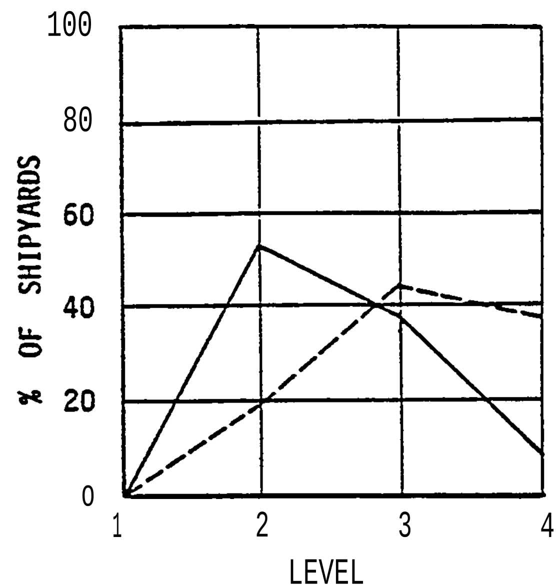
G 5

Parts Listing Procedures



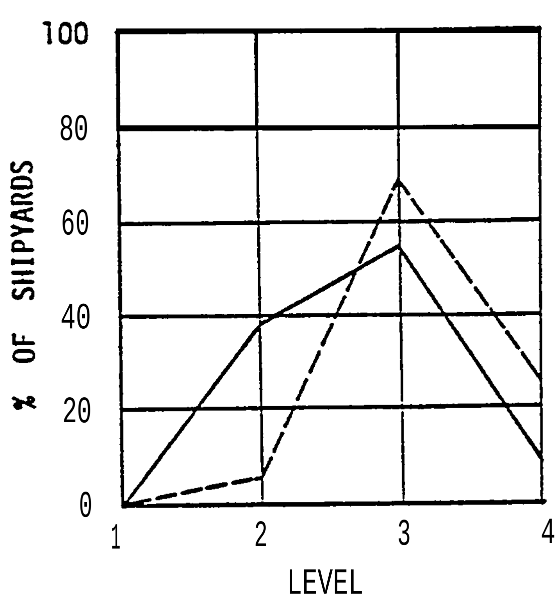
G6

Production Engineering



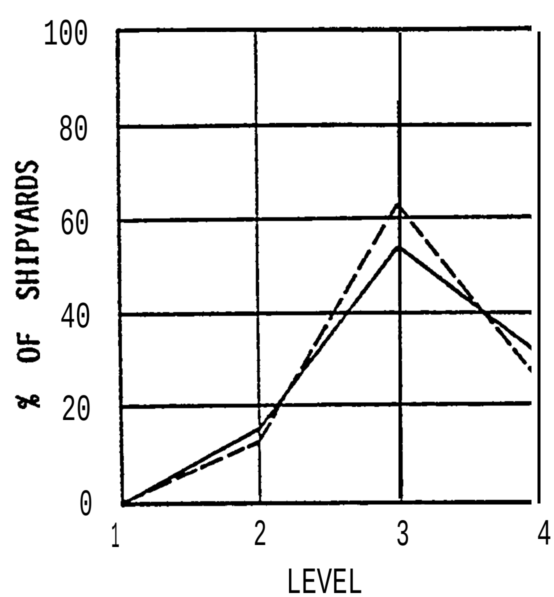
G7

Design for Production



G8

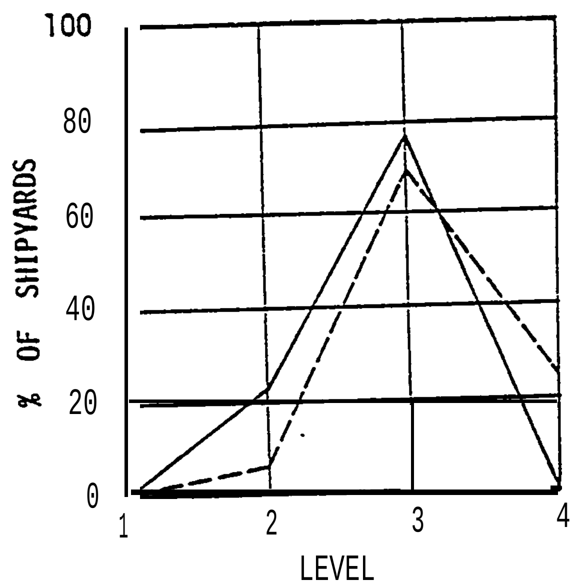
Dimensional & Quality Control



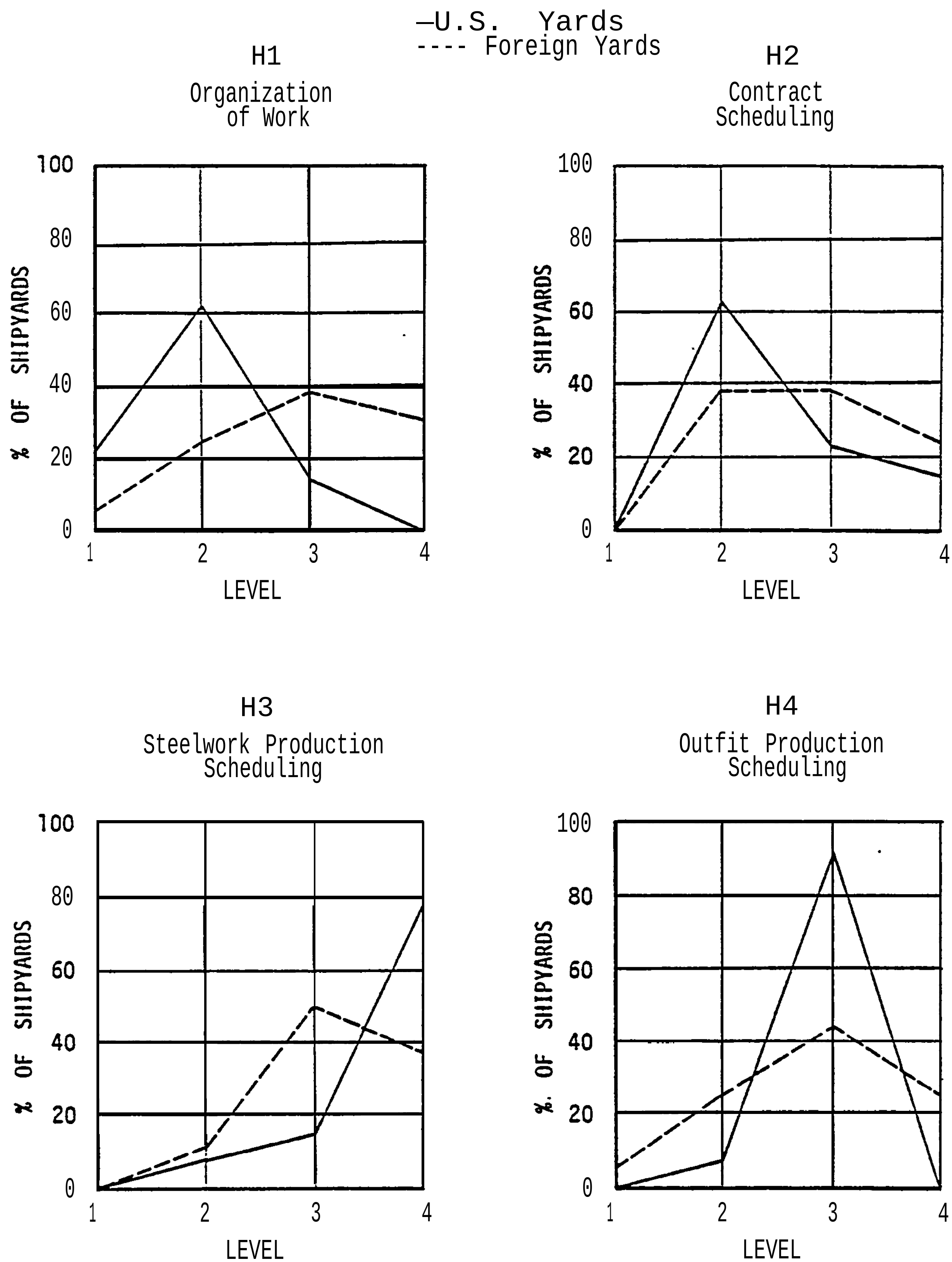
—U.S. Yards
----Foreign Yards

G 9

Lofting
Methods



H ORGANIZATION & OPERATING SYSTEMS

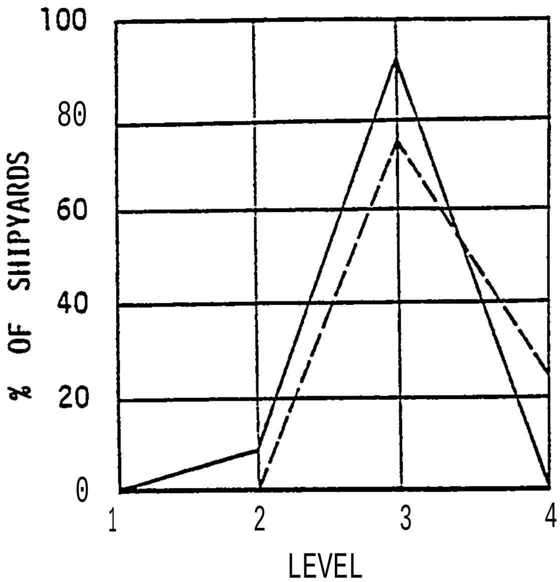


H ORGANIZATION & OPERATING SYSTEMS
(Continued)

—U.S. Yards
----Foreign Yards

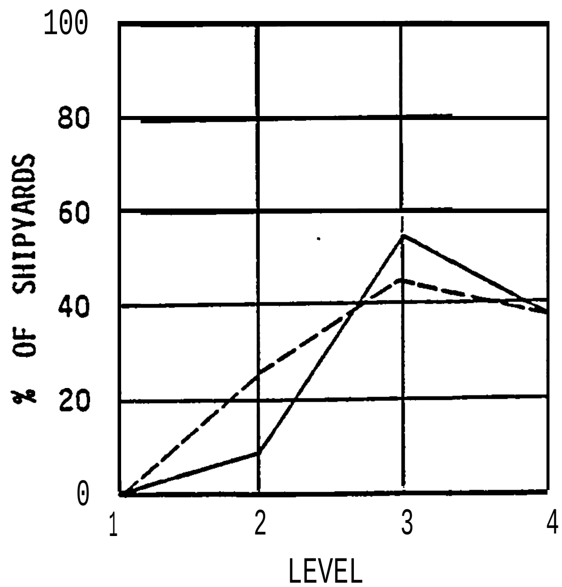
H5

Outfit Installation
Scheduling



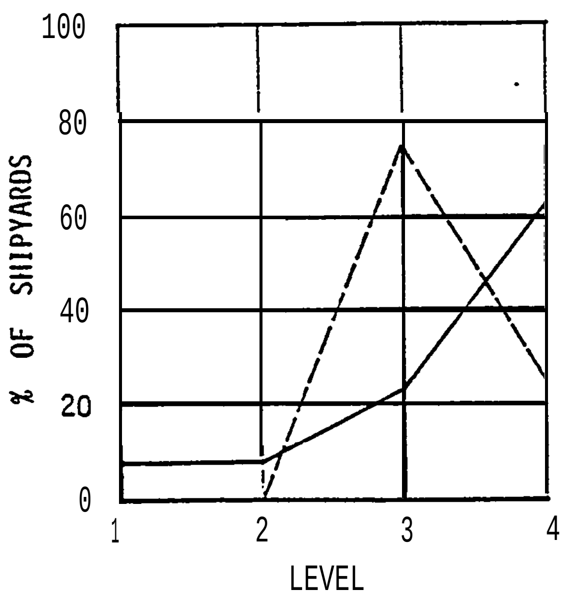
H6

Ship Construction
Scheduling



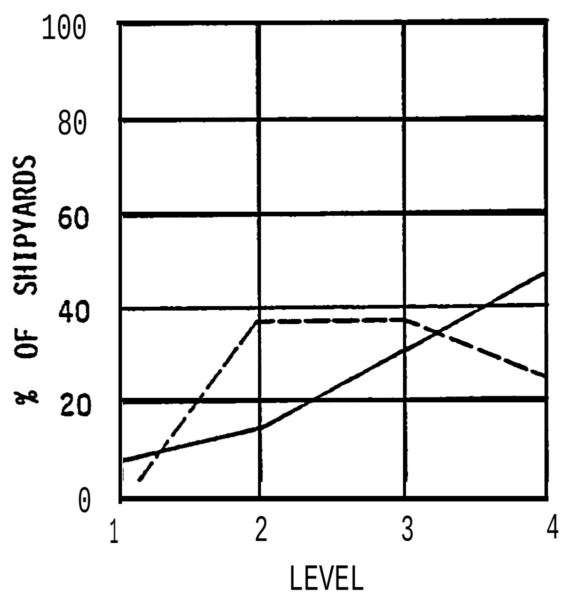
H 7

Steelwork Production
Control



Ha

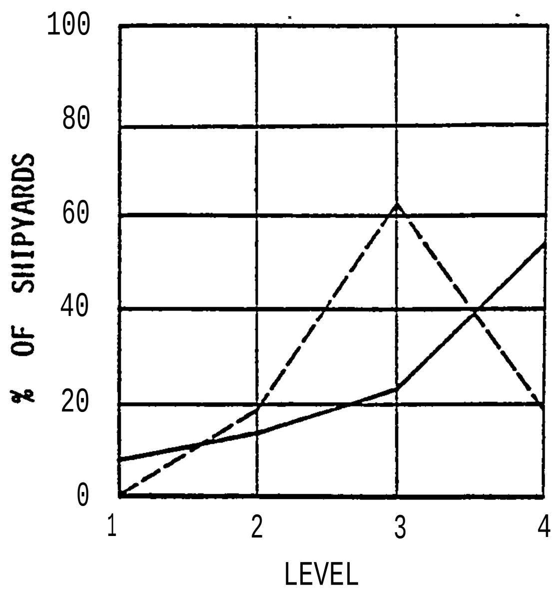
Outfit Production
Control



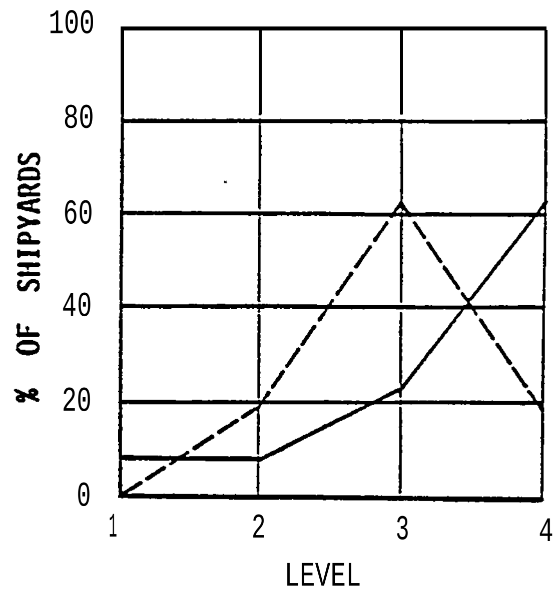
H ORGANIZATION & OPERATING SYSTEMS
(Continued)

—U.S. Yards
----Foreign Yards

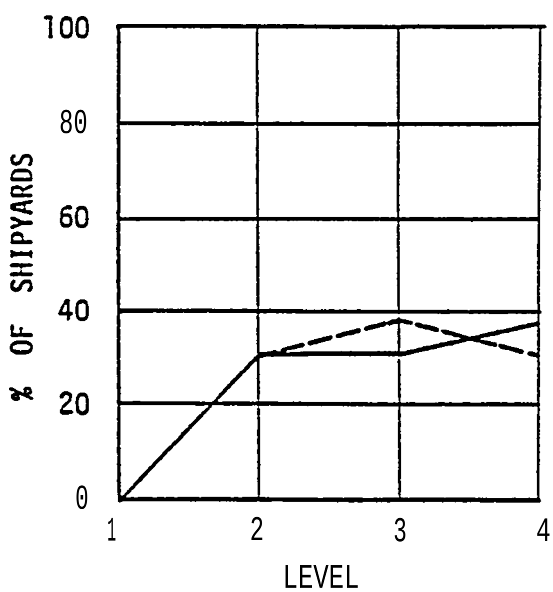
H9
Outfit Installation
Control



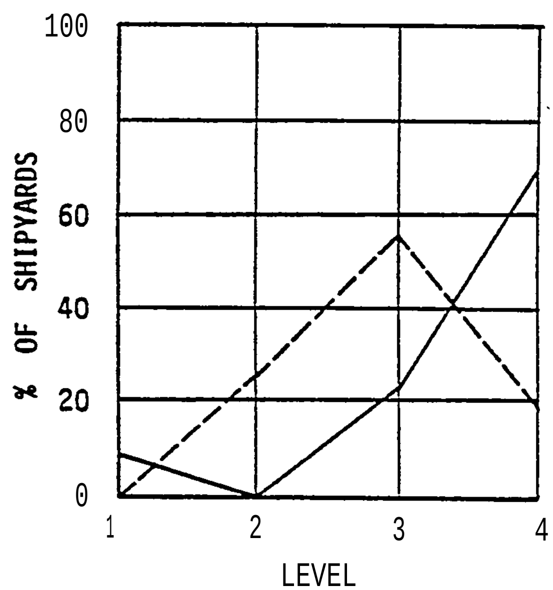
H 10
Ship Construction
Control



H 11
Stores
Control



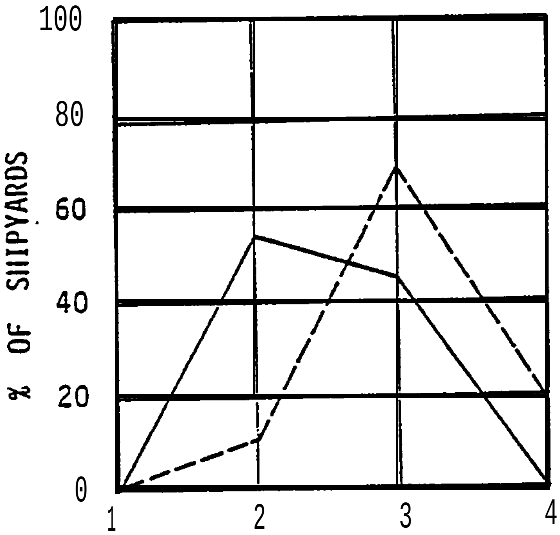
H 12
Performance &
Efficiency Calculations



H ORGANIZATION & OPERATING SYSTEMS
(Continued)

—— U.S. Yards
- - - - Foreign Yards

H 13
Computer
Applications



H 14
Purchasing